MUNICIPAL REFUSE DISPOSAL

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MUNICIPAL REFUSE DISPOSAL

A good refuse disposal program can serve a dual purpose. This picturesque public park in Memphis, Tennessee, is on land reclaimed by the sanitary landfill method of refuse disposal.

MUNICIPAL REFUSE DISPOSAL

Prepared by the
COMMITTEE ON REFUSE DISPOSAL
AMERICAN PUBLIC WORKS ASSOCIATION

Assistance provided by the
UNITED STATES PUBLIC HEALTH SERVICE
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

APWA Research Foundation Project 104

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FOREWORD

It is estimated that more than 90 million tons of refuse are produced each year in urban areas of the United States. Surveys by the American Public Works Association and the United States Public Health Service show that less than 50 per cent of the United States cities with populations of more than 2,500 dispose of community refuse by approved sanitary and nuisance-free methods. Approximately 80 per cent of the urban and rural communities with populations between 1,000 and 5,000 dispose of refuse in open dumps. Obviously, refuse is often handled with scant regard to sanitation standards, health hazards, and attendant blight in the immediate neighborhood and the entire community.

Mishandling is costlier than the use of good refuse disposal methods. The economic losses—in medical bills; fire and rodent damage; air and water pollution; use of makeshift insect sprays, traps, and poisons; exterminators' fees; and depreciated property values—can be staggering. Prompt and efficient collection and disposal of refuse are essential to environmental sanitation and the establishment of preventive health measures.

Many studies and reports have been made that provide a well founded basis for remedial action on a local or area basis. It has been four decades, however, since a comprehensive text of the thoroughness, scope, and authoritativeness required for nationwide application has been published.

The objective in this manual, therefore, is to review past and present disposal practices, principally in the United States; to gather pertinent data, bearing in mind geographic and seasonal differences; describe and analyze the best current practices; broadly indicate the costs; and discuss

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administrative and management problems. In short, provide authoritative information for officials responsible for refuse disposal in local, state, and federal governments.

Data on quantities of refuse produced regionally and seasonally, heretofore unavailable on this scale, were collected in cooperation with the United States Public Health Service through on-site studies in 12 cities known to have accurate statistical records. Data on equipment were solicited from manufacturers and are included on a selective basis.

To insure authoritativeness, the committee and task group members who prepared this book were selected with an eye to their recognized specialization in the refuse disposal field. They were also selected to represent government, the teaching profession, and private consultants, as well as various regions of the country.

The task group for each committee member did research, gathered and analyzed data, and with committee members wrote, reviewed, and revised each chapter. The dedicated and unstinting work and advice of all the committee and task group members are gratefully acknowledged. The assistance of public officials and consultants, who through discussions, questionnaires, and other media added invaluably to the manual, is also recognized.

Casimir A. Rogus
Chairman
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PREFACE

Publication of *Municipal Refuse Disposal* marks the completion of a task that required more than five years of intensive planning, research, and development by the American Public Works Association's Committee on Refuse Disposal.

The organization of a committee to undertake the preparation of the publication was authorized by the Board of Directors of the Association in 1955 upon the recommendation of Donald F. Herrick, then executive director of the Association and now retired, who called attention to the growing importance of solid waste disposal problems and the increasing demand for an authoritative manual on the subject. The successful completion of this project was made possible by financial grants from the APWA Research Foundation and the continuous cooperation and valuable assistance of the United States Public Health Service.

The Association gratefully acknowledges the excellent work of the parent committee and the task group members who gave generously of their time and knowledge to produce this comprehensive reference book, which will materially assist those concerned with the solution of refuse disposal problems. The Association likewise expresses its sincere appreciation to the publisher—Public Administration Service—for its splendid cooperation and particularly to Miss Jean Adams who was largely responsible for the final editing, indexing, and preparation of the manuscript for the printer.

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1 INTRODUCTION

The community that protects the health and safety of its residents and is clean and attractive must have an efficient, well organized refuse disposal system. Without one, disease-carrying rats, flies, and insects abound; water and air become polluted; fire hazards increase; unpleasant odors are common; and streets, parkways, lots, and alleys are littered and unattractive.

As the population of the United States increases and more and more people are concentrated in urban areas, the more acute the problem grows. Furthermore, as standards of living go up, the public demands better refuse disposal service. At the same time, the higher standards of living complicate the problem by increasing the amount of refuse produced.

Governmental Responsibility

No longer can local governments expect the people of a community to dispose of all of the rubbish, garbage, ashes, and other wastes that accumulate in their homes, plants, and businesses. To do so invites trouble and expense. Local governments have the responsibility for collection and disposal services even if they do not actually perform the services.

Responsibility for disposal services can be carried out in various ways. The municipality may (1) have its own crews dispose of refuse at municipally owned facilities; (2) contract with or license private collectors to dispose of refuse in municipally owned or private facilities, but with municipal control over practices; (3) pass ordinances specifying the ways in which refuse must be disposed of by householders, businesses, and industry (household or commercial garbage grinders, for instance, are required by law in some places, and the municipality collects and disposes of only nonputrescible refuse); and (4) use any combination of direct municipal and private disposal.

Regardless of whether the city takes direct responsibility for disposal, licenses or contracts with private collectors to do the work, or requires the producer to dispose of at least some refuse, the city must coordinate its disposal program with the collection service. The collection methods used may have a great deal of influence on the type of disposal service provided. Separate or combined collections of various kinds of refuse, frequency of collections, and other factors must all be considered in relation to the city's responsibility for disposal.

Most of the duties of municipal refuse handling agencies consist of collection and disposal of garbage, rubbish, and ashes. The collection of street refuse is usually a street cleaning function, with the refuse disposed of at facilities operated by the municipal sanitation or public works department. While the removal and disposal of dead animals is frequently one of the duties of a municipal refuse collection and disposal agency, it is often handled as a special problem rather than routinely. The responsibility for the removal of abandoned vehicles from the streets is frequently assigned to the street cleaning agency or to the police department. The vehicles are usually sold or given to junk dealers, who sell them for the spare parts or as scrap metal.

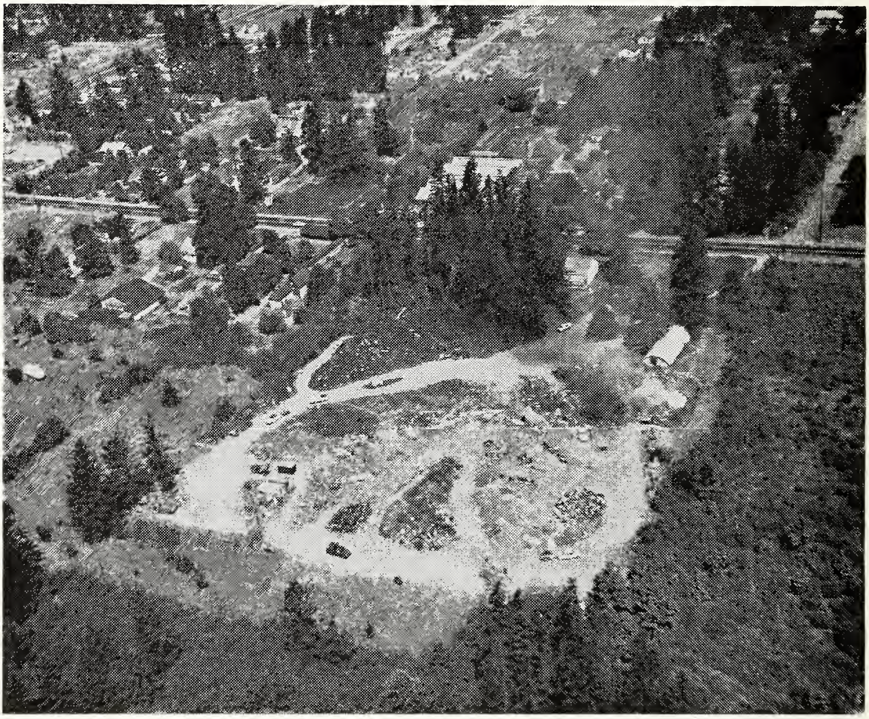


Fig. 1. The open dump is a crude means of refuse disposal and is particularly undesirable in a residential neighborhood. It is unsightly and creates odor and smoke nuisances as well as fire and health hazards.

Industrial refuse is not ordinarily considered a municipal responsibility, although there is a trend toward city collection of it and an even greater trend toward city disposal of some kinds of trade refuse. The disposal of demolition and construction refuse is the responsibility of the contractor in most cities, but it is sometimes accepted at municipal disposal facilities. Disposal of solid sewage wastes is sometimes the responsibility of the refuse disposal agency. Some such wastes can be incinerated at the municipal incinerator or they can be hauled to a sanitary landfill. Sanitary landfills are also used in some areas for disposing of septic tank sludge and sewage grit.

Special wastes or hazardous materials are nearly always present in refuse in small quantities. Large amounts are sometimes disposed of by special handling procedures at municipal disposal facilities.

The problem of disposing of refuse is not a new one. Nevertheless, solutions to the problem have undergone surprisingly little change in the long interval between the time man first threw an apple core on the ground beneath the tree from which he picked it and the time when he threw it out the window of a moving automobile. During this period, refuse disposal has dealt more with the *where* than the *how*. Evidence of the antiquity of this concept has been found inscribed on an old Roman signpost that warned, "Take your refuse farther or you will be fined."

The Dark Ages ended about 500 years ago, some experts claim, because of what has been called the greatest invention of all time—printing. By means of it knowledge has been disseminated and progress speeded. In modern times, the large amount of printed material has at least indirectly resulted in production of one of the most common and plentiful of refuse materials—paper. It has been reported that the United States government in Washington alone uses 150 carloads of paper each day. Paper and paper products are used in the United States at the rate of more than 400 pounds per person each year—much of it ending up as refuse that must be disposed of.

The idea that the individual can dispose of refuse without creating a greater nuisance than can be tolerated by an urban society long ago was proven unsound. As villages grew into towns and towns into large cities, the disposal of refuse inevitably became a function of local government. And because most residents of a city had no interest in refuse once it was beyond their sight and smell, the government usually had little choice except to concentrate the nuisance by dumping the refuse on the ground at a specific location. Thus because there is an aversion to spending money on materials discarded as worthless, the first criterion that developed for selecting a method of refuse disposal was that it be inexpensive.

Rapidly advancing sanitary standards and increased knowledge of the relation of environmental factors to public health have helped to modify criteria for acceptability until primitive disposal methods are no longer defensible on the basis of low cost alone. As the population of a metropolitan area increases, the number of acceptable dump sites in or near it decreases—almost to the vanishing point.

Aesthetics, water pollution problems, air pollution problems, and a host of other considerations have combined to make refuse disposal a serious engineering and planning undertaking.

The environmental health implications of poor community housekeeping extend beyond aesthetics and nuisances. There are serious health hazards connected with collection and disposal of solid wastes. Probably the first substantial scientific evidence in the United States that implicated a method of refuse disposal as a cause of a disease in human beings was obtained in the 1930's through studies of the incidence of trichinosis.

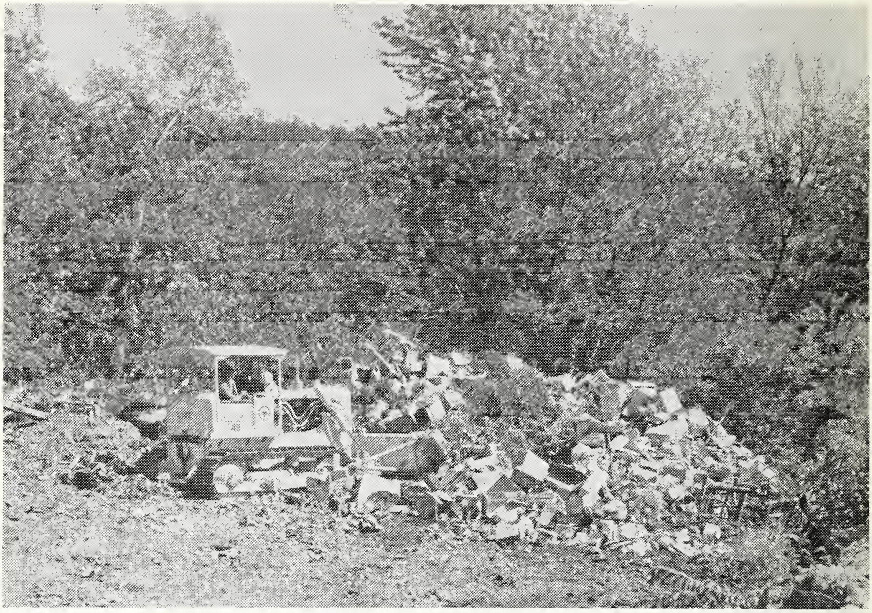


Fig. 2. Changing living habits have an effect on the kinds of refuse produced in a city. The rubbish content of refuse has increased in recent years while the ash and garbage content have decreased. Paper products and cardboard boxes are a large part of this refuse.

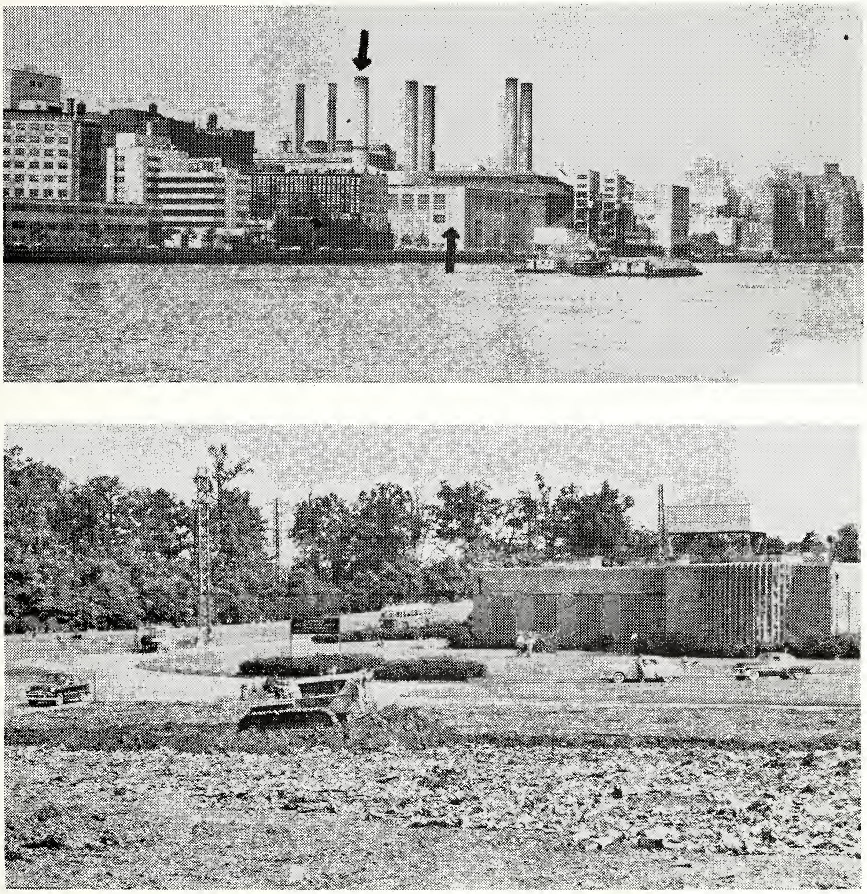
Using raw garbage as feed was identified as an important factor in the infection of hogs with the parasitic nematode trichinella spiralis. It was also determined that the infection was transmitted to humans when undercooked meat from the infected animals was eaten.

Although the reported morbidity rate for the disease was low and mortality was rare, the economic stakes were high. Many cities depended on hog raising to dispose of garbage. It was honestly believed that the relatively simple remedial measure of cooking the garbage before it was fed to the hogs would bring chaos to the hog raisers and probably create more garbage disposal problems than the step was supposed to remedy. It was not until 1952, when the spectacular epizootic of vesicular exanthema caused an agricultural emergency and raised the economic stakes, that cooking of garbage was required.

Higher living standards and increased production in many ways affect the problem of refuse disposal. Not only is refuse increasing in volume but also the characteristics of refuse are constantly changing. In short, refuse production is directly related to the whole national economy and the behavior patterns of the people. Consequently, disposal facilities must be planned with the ever-changing amounts and kinds of refuse in mind.

Evolution of Disposal Methods

The idea of systematic collection and disposal of refuse is relatively new in the civilized world. Although disposal by dumping and burning was known to ancient civilizations, systematic collection and disposal were not common even in the major cities of the world until well into the nineteenth century. Up until then city dwellers threw refuse and excrement onto unpaved streets and roadways where it mingled with droppings of domestic animals. Even in the Golden Age of ancient Greece "the



Figs. 3 and 4. The New York City East 73rd Street incinerator (above) is a good neighbor, even in this crowded commercial, industrial, and residential area. New apartments in the neighborhood rent for as much as $100 a month per room. Sanitary landfills are also good neighbors. The final layer of compacted earth cover is being put on this one (below) next to a park and an electrical company substation in Memphis.

narrow, crooked streets of Athens were heaped with refuse."[1] The same was typical of European cities and towns in the Middle Ages. In fact, the plagues and epidemics that swept whole countries and continents resulted in large measure because there were no systems of refuse disposal or they were hopelessly inadequate. Although there were local ordinances against dumping refuse in the streets for many centuries in cities of the Western world, there was little popular support or enforcement of them until bacteriology and epidemiology studies laid the foundation for today's sanitary science. It was then that the relationship between refuse disposal and disease-carrying flies, mosquitoes, rats, and other vermin was proven.

Disposal of refuse by open dumping and burning undoubtedly antedates recorded history. Feeding garbage to hogs and the use of inorganic wastes for fill are also ancient practices. Composting of organic wastes has been traced as far back as the Kouloure pits in Cnossus, an ancient capital of Crete, which flourished some 40 centuries ago; and disposal of wastes by burial, the precursor of today's sanitary landfills, dates back at least to Biblical times. Furnaces to burn refuse were designed in the latter part of the nineteenth century; garbage reduction was introduced in the 1880's; garbage grinding began in the early 1920's.

Magnitude of the Problem

Refuse disposal is primarily an urban problem and the more concentrated the population is the greater the problem becomes. Costs also vary according to the size of the population served. According to reports of the 1960 census, the urban population of the United States is about 70 per cent of the total—125.3 million out of 179.3 million. The rural population of about 54 million makes up the remaining 30 per cent (Table 1). It is significant that between 1950 and 1960 the total population of the country increased by about 18.5 per cent, but the rural population decreased by a fraction of 1 per cent (about 425,000) while the urban

Table 1

URBAN AND RURAL RESIDENCE OF THE POPULATION OF THE UNITED STATES: 1950 AND 1960

Residence	*1960*		*1950*		*Change*	
	Number	*Per Cent of Total*	*Number*	*Per Cent of Total*	*Number*	*Per Cent of Total*
Urban	125,268,750	69.9	96,846,817	64.0	+28,421,933	+29.3
Rural	54,054,425	30.1	54,478,981	36.0	—424,556	—0.8
Total	179,323,175	100.0	151,325,798	100.0	+27,977,377	+18.5

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[1] T. W. Wallabank and A. M. Taylor, *Civilization Past and Present* (Rev. ed., Vol. 1; Chicago: Scott, Foresman and Co., 1949), p. 148.

Table 2

NUMBER AND POPULATION OF URBAN PLACES BY POPULATION SIZE AND TYPE FOR THE UNITED STATES: 1960

Population Size	*All Places*		*Incorporated Places*		*Unincorporated Places*		*Urban Towns and Townships*	
	Number	*Population*	*Number*	*Population*	*Number*	*Population*	*Number*	*Population*
1,000,000 or more	5	17,484,059	5	17,484,059	0	...	0	...
500,000 to 1,000,000	16	11,110,991	16	11,110,991	0	...	0	...
250,000 to 500,000	30	10,765,881	30	10,765,881	0	...	0	...
100,000 to 250,000	81	11,652,426	79	11,384,755	1	104,270	1	163,401
50,000 to 100,000	201	13,835,902	180	12,511,961	9	585,104	12	738,837
25,000 to 50,000	432	14,950,612	366	12,720,406	26	858,459	40	1,371,747
10,000 to 25,000	1,134	17,568,286	978	15,061,679	101	1,565,850	55	940,757
5,000 to 10,000	1,394	9,779,714	1,282	9,030,786	104	688,135	8	60,793
2,500 to 5,000	2,152	7,580,028	1,763	6,237,739	379	1,304,265	10	38,024
Total	5,445	114,727,899[1]	4,699	106,308,257	620	5,106,083	126	3,313,559

[1] Urban population in urban places only.

population increased by nearly 30 per cent (about 28.4 million). These figures are based on the definition of "urban" that was used in the 1960 census.[2] Table 2 shows the number and population of urban places by size and type for the United States in 1960. (Tables 1 and 2 are adapted from *Municipal Year Book, 1961;* International City Managers' Association.)

Fig. 5. The disposal operation must be dependable. If equipment fails, large quantities of accumulated refuse may become nuisances and hazards to health.

The results of a study of quantities of refuse disposed of in 12 United States cities, made in 1959 especially for this book, show that quantities ranged from 794 pounds per capita per year (not including refuse that is usually salvaged) to 1,690 pounds, with a median of 1,430 pounds. (Some earlier studies show a wider range—from 125 pounds per capita to 1,800 pounds. Some such studies are of uncertain accuracy, however, because local officials answering questionnaires used different definitions, had different collection practices, and had different record keeping methods.)

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[2] The urban population includes all persons living in (1) places of 2,500 inhabitants or more incorporated as cities, boroughs, villages, and towns (except towns in New England, New York, and Wisconsin); (2) the densely settled urban fringe, whether incorporated or unincorporated, of urbanized areas; (3) towns in New England and townships in New Jersey and Pennsylvania that contain no incorporated municipalities as subdivisions and have either 25,000 inhabitants or more or a population of 2,500 to 25,000 and a density of 1,500 persons or more per square mile; (4) counties in states other than the New England states, New Jersey, and Pennsylvania that have no incorporated municipalities within their boundaries and have a density of 1,500 persons or more per square mile; and (5) unincorporated places of 2,500 inhabitants or more.

If the median was 1,430 pounds per capita per year, the total refuse produced in urban areas of the United States in 1960 was an astounding 180 billion pounds or more!

The annual bill for municipal refuse disposal in the United States is estimated at some $400 million and another estimated $1.1 billion are spent for collection of refuse—for a total bill of $1.5 billion annually.

National totals and averages cannot be used in determining the amounts of refuse to be disposed of locally, however. Studies show that there are wide differences in amounts collected and disposed of by municipalities because of differences in climate, living standards, and collection and disposal practices. Furthermore, within a city there are marked fluctuations in daily and seasonal amounts.

Refuse Materials Defined

One of the first and most perplexing problems confronting a newcomer to the field of refuse collection and disposal is the vocabulary of the field. To most people in the United States there are "garbage men" who collect "garbage" from "garbage cans" and haul it to "garbage dumps" in "garbage trucks." The public often refers to a sanitary landfill as a garbage dump or to a rubbish collection as a garbage collection.

If a person uses a dictionary, he finds "garbage" means "trash," which is "refuse," which means "rubbish," which again means "trash" or "debris." There are more than 30 synonyms for "garbage" in Roget's *Thesaurus*.

It is common for a city to use one of the many synonyms such as "garbage," "rubbish," or "refuse" to mean all the materials it collects and disposes of. Adding to the confusion in terminology is the wide variation in the refuse collection practices of different cities. For example, some cities collect table scraps, waste paper, tin cans, bottles, and other miscellaneous household wastes and call them "garbage," while other cities use the term "rubbish" to mean the same material. This lack of a common terminology is confusing and leads to numerous uncertainties and even errors in interpreting published information.

Refuse collection and disposal problems must be discussed generally in terms of the collection and disposal of the component substances of refuse. It appears essential, therefore, to define the words and terms used to identify different classes of refuse and to state what materials make up each class.

The terms used in this manual to refer to refuse and its component materials are defined in the following paragraphs (see also Table 3). The definitions are those most widely used among persons engaged in refuse collection and disposal. For purposes of standardization, they are based on those in the 1958 revised edition of *Refuse Collection Practice*.[3]

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[3] American Public Works Association, Committee on Refuse Collection, *Refuse Collection Practice* (2 ed.; Chicago: Public Administration Service, 1958), pp. 13-52.

Table 3

REFUSE MATERIALS BY KIND, COMPOSITION, AND SOURCES

Kind		*Composition*	*Sources*
Refuse	Garbage	Wastes from preparation, cooking, and serving of food; market wastes; wastes from handling, storage, and sale of produce	Households, restaurants, institutions, stores, markets
	Rubbish	Combustible: paper, cartons, boxes, barrels, wood, excelsior, tree branches, yard trimmings, wood furniture, bedding, dunnage	
		Noncombustible: metals, tin cans, metal furniture, dirt, glass, crockery, minerals	
	Ashes	Residue from fires used for cooking and heating and from on-site incineration	
	Street Refuse	Sweepings, dirt, leaves, catch basin dirt, contents of litter receptacles	Streets, sidewalks, alleys, vacant lots
	Dead Animals	Cats, dogs, horses, cows	
	Abandoned Vehicles	Unwanted cars and trucks left on public property	
	Industrial Wastes	Food processing wastes, boiler house cinders, lumber scraps, metal scraps, shavings	Factories, power plants
	Demolition Wastes	Lumber, pipes, brick, masonry, and other construction materials from razed buildings and other structures	Demolition sites to be used for new buildings, renewal projects, expressways
	Construction Wastes	Scrap lumber, pipe, other construction materials	New construction, remodeling
	Special Wastes	Hazardous solids and liquids: explosives, pathological wastes, radioactive materials	Households, hotels, hospitals, institutions, stores, industry
	Sewage Treatment Residue	Solids from coarse screening and from grit chambers; septic tank sludge	Sewage treatment plants; septic tanks

Waste

The word waste refers to useless, unused, unwanted, or discarded materials. Waste includes solids, liquids, and gases. The gases are principally industrial fumes and smoke; the liquids consist mainly of sewage and the fluid part of industrial wastes; the solids are classed as refuse.

It is difficult to classify municipal wastes or to state absolutely the kinds of materials that constitute the part called refuse. Part of the solid refuse materials produced in a city, particularly particles of garbage and rubbish, finds it way into sewers and is disposed of with the liquid sewage wastes. And some semiliquid food wastes are accepted by private collectors of refuse as swill for hog feeding.

Refuse

The term refuse refers to solid wastes. Its component materials can be classified in several different ways. The point of origin is important in solving some problems, so that classifying as domestic, institutional, commercial, industrial, street, demolition, or construction is useful. For other problems, the point of origin is not as important as the nature of the material and classification may be made on the basis of organic or inorganic character, combustibility or noncombustibility, putrescibility or nonputrescibility. One of the most useful classifications is based on the kinds of materials: garbage, rubbish, ashes, street refuse, dead animals, abandoned automobiles, industrial wastes, demolition wastes, construction wastes, sewage solids, and hazardous and special wastes. Table 3 groups refuse materials by kind, composition, and indicates in a general way the source of the refuse.

Garbage

Garbage is the animal and vegetable waste resulting from the handling, preparation, cooking, and serving of foods. It is composed largely of putrescible organic matter and its natural moisture; it includes a minimum of free liquids. The term does not include food-processing wastes from canneries, slaughterhouses, packing plants, or similar industries; large quantities of condemned food products; or oyster or clam shells, which ordinarily are considered industrial wastes. Garbage originates primarily in home kitchens, stores, markets, restaurants, and other places where food is stored, prepared, or served.

Garbage decomposes rapidly, particularly in warm weather, and may quickly produce disagreeable odors. When carelessly stored, it is food for rats and other vermin and is a breeding place for flies.

There is some commercial value in garbage as animal food and as a base for commercial animal feeds. It may also have some value for its grease content or as a plant fertilizer after processing. These uses are fully discussed in later chapters.

The terms "swill," "slops," and "offal," which are frequently found in city ordinances to define garbage, are not synonymous with garbage. "Swill" and "slops" connote semiliquid garbage and free liquids. Where cities do not collect and dispose of such materials, hog raisers operating as private collectors usually collect it from restaurants and institutions for use as hog feed. The word "offal" has had so many different meanings that its use is avoided in this book except as it refers to discarded parts of slaughtered animals.

Market refuse is a special type of garbage that results from the handling, storage, and selling of foods at wholesale and retail stores and markets. It originates principally in meat, poultry, fish, vegetable, and fruit markets, and includes large quantities of putrescible food wastes along with some rubbish, such as wooden crates and cardboard boxes. It also includes some condemned foods but not large quantities of spoiled material.

As market refuse is usually highly putrescible, the protection of the fresh food supply and the appearance of the community make frequent collection of it necessary. In many cases official city agencies collect and dispose of it.

Rubbish

Rubbish consists of a variety of both combustible and noncombustible solid wastes from homes, stores, and institutions. This waste is defined more specifically as "combustible rubbish" and "noncombustible rubbish,"

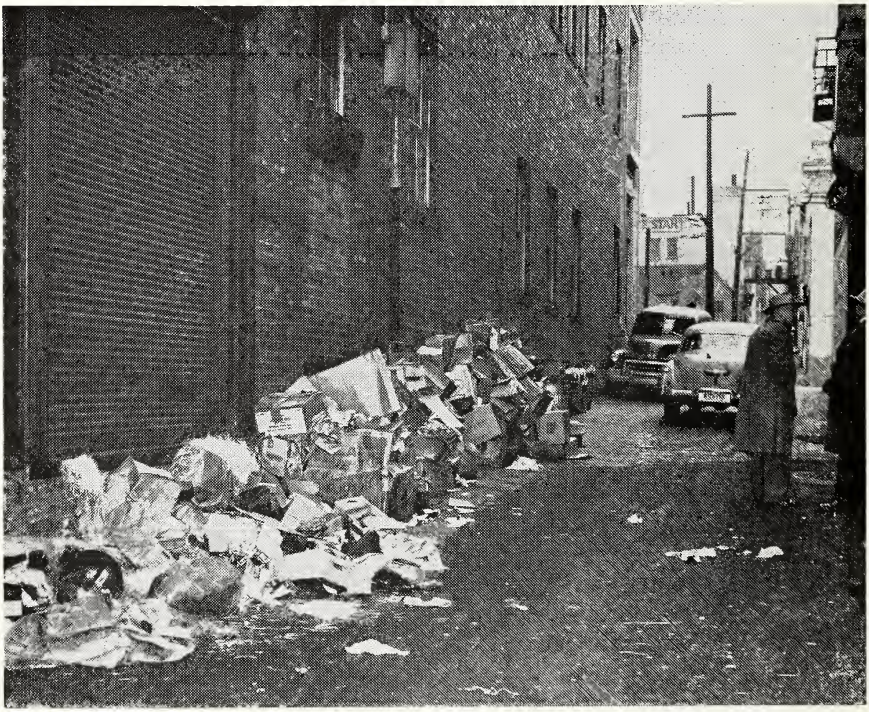

Fig. 6. The best disposal system is of little value if collections are inadequate. This accumulation of refuse is so bad that traffic is obstructed. The relationship between good street cleaning, a good refuse collection system, and good disposal methods is obvious from this picture.

but whenever the term "rubbish" is used alone it means a mixture of combustible and noncombustible wastes. "Trash" is synonymous with "rubbish" but the term is not used in this book. If garbage is collected with rubbish it is necessary to have more frequent collections than if rubbish is collected separately.

Combustible rubbish is burnable material. In general, it is the organic component of refuse—paper, rags, cartons, boxes, wood, excelsior, furniture, bedding, rubber, plastics, leather, tree branches, lawn trimmings, and the like. Some cities use this term for only designated burnable materials that are accepted in regular collections. In such cases, some materials, such as food cans and bottles, are specifically included or excluded in the definitions of "rubbish" in the ordinance.

Combustible rubbish, though organic, is not highly putrescible, and therefore may be stored for relatively long periods without becoming a nuisance. It has high heat value and when dry it burns freely without forced draft and without added fuel. Often it is collected with wrapped garbage to provide the fuel necessary to burn garbage in an incinerator. Paper, rags, and cartons may have salvage value.

Noncombustible rubbish is material that is unburnable at ordinary incinerator temperatures (1,300° to 2,000° F.). For the most part, it is the inorganic component of refuse, such as tin cans, heavy metal, mineral matter, glass, crockery, dust, metal furniture, ashes, and the like.

Although some of the metals undergo slow disintegration by oxidation, noncombustible rubbish is stable. When carelessly stored, however, it is aesthetically objectionable and it may harbor rodents and other vermin.

There has been a great deal of discussion among sanitary engineers and public health officials about the proper classification of tin cans that have been used as food containers and, when discarded, have particles of putrescible organic matter clinging to them. Because of this organic matter, some argue that cans should be included with garbage. It is now fairly generally accepted, however, that under ordinary conditions the organic matter desiccates rather than putrefies. For this reason, food cans and bottles may be included with noncombustible rubbish.

The metals, tin cans, bottles, and broken glass in noncombustible rubbish may have salvage value when prices are high.

Yard rubbish consists of tree branches, twigs, grass and shrub clippings, weeds, leaves, and other yard and garden waste materials. When collected, it often contains earth clinging to roots of grass, weeds, and discarded plants. Yard rubbish is usually a part of the combustible rubbish category rather than a category by itself. It is separately defined, however, because many cities make different arrangements for its collection and disposal from those for other combustible refuse and because some municipalities exclude it entirely from their collection service, leaving disposal up to the householder. Collection and disposal of palm fronds in some areas is a problem requiring special techniques.

A considerable part of yard rubbish is green vegetation, which, when kept moist or when stored in large amounts, decomposes fairly rapidly.

It is not ordinarily objectionable but under some conditions it may be a breeding place for insects. This green material can be burned in an incinerator but normally it will not sustain a fire alone. Banana stalks are especially troublesome in this respect. Dried vegetation, dead leaves, and plants do not cause a sanitary nuisance and ordinarily will burn readily in an open fire. They can also be disposed of with other rubbish.

Ashes

Ashes are the residue from wood, coal, coke, and other combustible material burned in homes, stores, institutions, and small industrial establishments for heating, cooking, and disposing of combustible waste material. Residues produced in large quantities at steam generating plants are not included within the meaning of the term, since they are normally not the responsibility of a municipality.

Ashes are usually composed of a mixture of fine powdery residue, cinders, clinkers, and small portions of unburned or partially burned fuel or other material. Small pieces of metal, glass, and combustible materials are usually found in ashes when they are collected. Since the mixture is almost entirely inorganic, it is valuable for fills on low land, even in or near built-up communities, and it is acceptable some places for maintaining unpaved streets. Except for the dust that they can cause, ashes are not objectionable from a nuisance or aesthetic standpoint. In cities in which combustible and noncombustible refuse are separated for collection many cities ask that such noncombustibles as broken crockery, cans and bottles that are not food containers, and all metals be discarded with the ashes.

The residue in household refuse incinerators and yard rubbish burners is sometimes classed as ash, as are the remains from leaves and other yard rubbish burned in open fires. However, when garbage is only partly burned in low-temperature, inefficiently operated domestic incinerators, local authorities may require that the contents of incinerator pits be stored and collected as garbage or combustible refuse or they may refuse to collect them. In such cases, the incinerator or the operation of it should be modified so that garbage can be burned to ash, or attempts to incinerate garbage should be discontinued.

Street Refuse

Street refuse is material picked up by manual and mechanical sweeping of streets and sidewalks and litter from public litter receptacles. It includes paper, dirt, leaves, and the like. All or part of it is usually disposed of at a municipal disposal facility. Some cities assign the task of collection and disposal of street refuse to the regular refuse collection and disposal agency, while others assign it to the street department.

Dead Animals

As a category of refuse, dead animals are those that die naturally or from disease or are accidentally killed. Condemned animals or parts of animals from slaughterhouses or similar places are not included; they are regarded as industrial refuse.

Dead animals are ordinarily classified into one of two groups—"large" or "small." Large animals are horses, cows, goats, sheep, hogs, and the like. Small animals include dogs, cats, rabbits, squirrels, and rats. Some coastal cities frequently have problems with dead fish and dead aquatic mammals that float ashore at beaches. Collection of large animals usually requires special equipment.

Large animals have value because of the grease and tankage that can be produced from them in rendering plants. Their hides also have some value.

Dead animals are particularly offensive from sanitary and aesthetic points of view and usually must be collected promptly—often on an emergency basis. They putrefy rapidly, particularly in warm, moist atmosphere, and attract flies and other insects. Animal traffic victims are sometimes crushed by vehicles passing over them and therefore must be picked up promptly.

Abandoned Vehicles

Abandoned vehicles include passenger automobiles, trucks, and trailers that are no longer useful and have been left on city streets and in other public places. Usually they are found stripped of tires, wheels, lights, and other easily salvaged parts. While they must be removed from

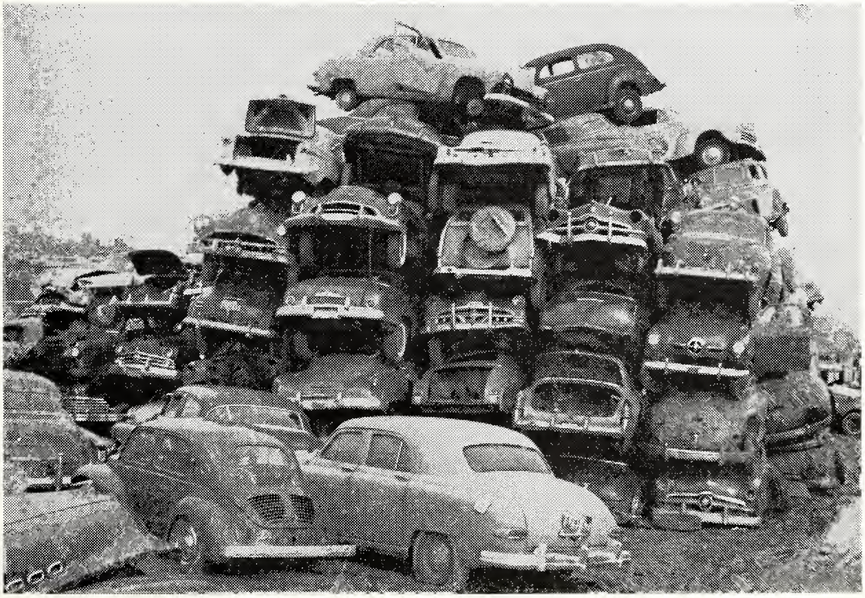

Fig. 7. Abandoned automobiles are a problem if there is little or no demand for scrap metal. They are bulky and difficult to handle if they cannot be salvaged.

the streets by municipal authorities, the task is not usually considered a part of the work of the regular refuse collection agency, but a duty of the street cleaning, highway, or police forces.

Industrial Refuse

Industrial refuse consists of solid waste materials from factories, processing plants, and other manufacturing enterprises. The collection of such matter is rarely regarded as an obligation of the city or a governmental function, but as an obligation of industry. Refuse of this category includes putrescible garbage from food processing plants and slaughterhouses, condemned foods, building rubbish, cinders from power plants, and manufacturing refuse.

Because putrescible industrial refuse may cause serious nuisances and even endanger public health, its storage, hauling, and disposition are subject to municipal control, and many municipalities are now providing for disposal of this type of refuse.

Demolition Refuse

Demolition refuse is the waste material from razed buildings or other structures. It is found mostly in cities in which extensive areas of old or otherwise obsolete buildings are being torn down to make way for new structures. The federally-aided program of urban renewal has given impetus to these programs in recent years. The construction of new expressways in large cities also necessitates the destruction of many buildings and adds to the demolition refuse problem.

Demolition refuse is not usually collected by municipal agencies. Usually the company wrecking a building contracts to haul the debris away and dispose of it. In some cities, however, particularly if large landfill areas are available, the city allows wreckers to dump refuse at its disposal facility for a slight charge, or even free. (See Chapter 3, section on special disposal problems.)

Construction Refuse

Construction refuse is the waste material from the construction, remodeling, and repair of houses, commercial buildings, and other structures. It includes a great variety of matter, such as earth, stones, bricks, plaster, wallpaper, lumber, shingles and other roofing, concrete, plumbing parts, old heating systems, and worn out electrical parts.

A small amount of such refuse is usually accepted from households and stores but the bulk of it is considered industrial refuse that contractors and builders must remove. A municipality may agree to dispose of it but if it does, it creates problems. (See Chapter 3, section on special disposal problems.)

Sewage

The disposal of some sewage solids is the responsibility of the municipal refuse disposal agency in many areas. Large, coarse solids, mostly organic, are screened from the influent at the sewage treatment plant,

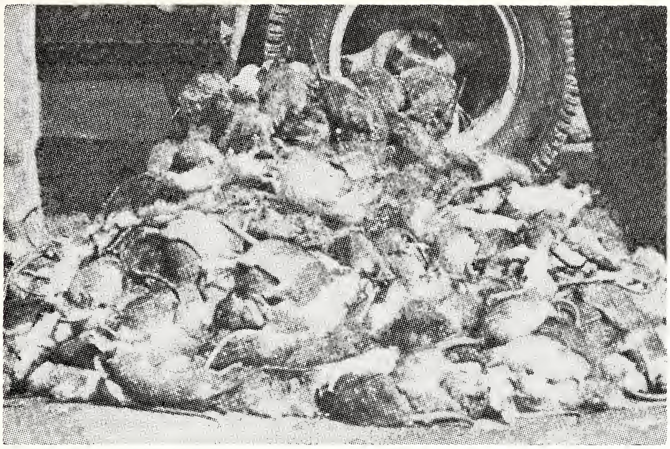

Fig. 8. Serious public health problems may arise if improper refuse disposal methods are used. These rats inhabited an open dump until they were poisoned in a campaign against them.

and if a municipal incinerator or sanitary landfill is convenient to the treatment plant these solids are disposed of by one method or the other. Solid inorganic matter from grit chambers may also be disposed of in a nearby sanitary landfill. This grit, however, even after going through a washing process, may contain substantial quantities of highly putrescible matter, and it is necessary, therefore, to bury it to effectively prevent an odor nuisance. Septic tank and cesspool pumpings are often disposed of in sanitary landfills in the absence of a sewage treatment plant, again under rigid controls to avoid nuisances.

Hazardous or Special Refuse

Waste material that presents an unusual disposal problem or requires special handling comes within the definition of hazardous, or special, waste. Small quantities of such wastes are usually present in ordinary refuse. A small can of paint or paint thinner, a roll of photographic film, or a plastic household article is not hazardous and can be disposed of by incineration or landfill without special handling. On the other hand, large quantities of the same materials create problems that require special procedures to prevent explosions in an incinerator furnace or a dangerous fire at a sanitary landfill. Even under the strictest safety measures, such explosions occur.

On the other hand, some wastes from industry are hazardous under any conditions, and pathological wastes from hospitals and radioactive materials require special handling no matter the quantity.

2 QUANTITIES AND COMPOSITION OF REFUSE

The amount and types of refuse collected and disposed of by official disposal agencies in United States cities have varied widely over the years. Most cities do not collect all the wastes produced within their limits because of either voluntary or mandatory self-disposal by the producers of wastes. Also, the amounts produced and collected vary according to whether a community is primarily industrial, residential, or business, the habits of the people, living standards, the season of the year, the frequency of collection, the geographical location of the city, and with the extent of use of on-the-premises disposal equipment, such as food grinders and domestic incinerators. Even within a community there are differences from day to day, week to week, and year to year, depending on weather and changing economic and other conditions.

QUANTITIES

It is important to know within reasonable limits, however, the amount of refuse that a government agency must collect or supervise the collection of, and how it is to be disposed of. It is essential to have that information in determining the most suitable and economical plan for collecting the refuse, establishing collection routes, selecting the right kind of collection equipment, determining the best disposal method, and providing the number of men and vehicles necessary to do the work efficiently. Some cities keep accurate records, by categories, of the amount of refuse they collect, and effectively use these data in the administration of their collection and disposal program. For example, the data can disclose trends that can be used as a basis for determining future facility needs; and the data can be used to help judge operational efficiency. Many city agencies, however, have little or no information on the amount of refuse they handle, and therefore must use the experiences of other cities to determine how much refuse they probably will have to collect and dispose of.

Measuring Quantities

Some cities weigh only garbage or garbage and combustible rubbish, while others weigh all refuse—but in both the amounts are recorded in pounds or tons. As more and more municipalities have weighed refuse, the ton has been used more frequently as the standard unit of weight. For convenience in determining the amount of refuse collected on a population basis, however, pounds per capita per calendar day or per year are usually used.

A great many municipalities, on the other hand, do not have scales for weighing refuse, but keep data on the amounts on a volume basis. The cubic yard, as measured in the collecting vehicle, is the unit used. If the volume is carefully measured or estimated the resulting statistics are of value to local authorities. For comparative purposes, however, there are several reasons why volume is not as satisfactory as weight. In some places refuse is loosely thrown into collection vehicles, while in others it is tightly compacted by using mechanical compactor-type vehicles or by the collection crews, which break up bulky articles and compress the loads by trampling. The weight per cubic yard of a given type of refuse varies greatly with the type of truck used and the methods the crew uses to load it. An open truck, for example, may carry from 150 to 300 pounds per cubic yard of the same type of rubbish, depending on how it is loaded and trampled. An enclosed truck can vary even more markedly in the weight it carries per cubic yard. When collected in a modern compaction truck, refuse can vary from 150 pounds per cubic yard if the crew neglects to load it properly to more than 500 pounds per cubic yard if the refuse is properly loaded and compacted. A load of noncombustible refuse with heavy ash content may weigh as much as 1,000 pounds per cubic yard. Unit weights are discussed in greater detail later in this chapter.

When refuse is taken to dumps or sanitary fill sites, scales are not usually available. Quantities are reported on a volume basis, therefore,

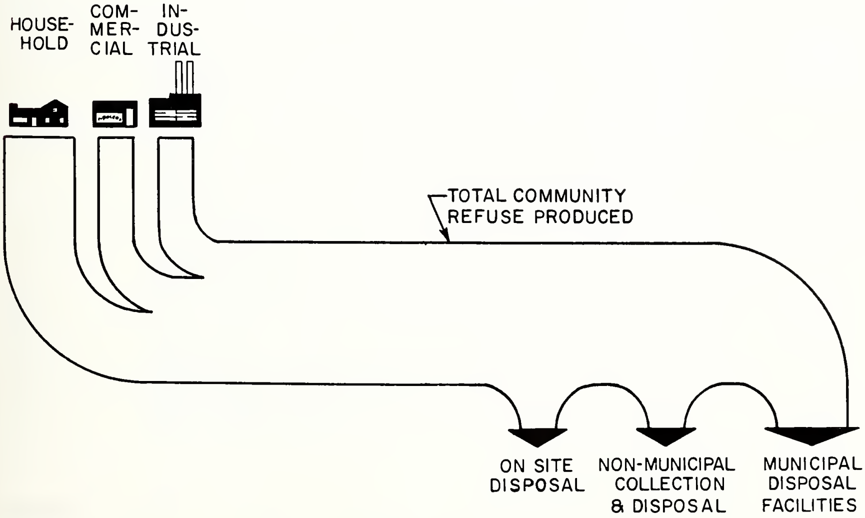
HOUSE-HOLD
COM-MER-CIAL
IN-DUS-TRIAL
TOTAL COMMUNITY REFUSE PRODUCED
ON SITE DISPOSAL
NON-MUNICIPAL COLLECTION & DISPOSAL
MUNICIPAL DISPOSAL FACILITIES

Fig. 9. Private collection and disposal and on-premise disposal and salvage influence the quantities of refuse collected and disposed of by a municipality from homes, industries, and businesses. Consequently, municipal disposal facilities often are provided for only a part of all the refuse produced in a city. Some cities, however, collect and dispose of practically all refuse.

which at best is only roughly comparable to the weight. When refuse is disposed of in a sanitary landfill it is important to measure the volume of the refuse *after* compaction. This helps to estimate the life of the fill area, and if in addition the weight is known, the density of the compacted refuse can be calculated and compared with other types of disposal operations.

Quantities Produced, Collected, and Disposed of

The amount of refuse picked up by the regular collection agency is always somewhat less than the amount produced in the community, the difference depending largely on the amount of self-disposal by industry and residents, the efficiency and extent of the service, the amount of on-the-premises disposal, and the amount of refuse salvaged before collection.

Some garbage and combustible rubbish is burned in household furnaces and stoves during some seasons of the year, not only because it produces heat but also because it is often much more convenient for the householder than collection and it costs less if collection is charged for directly. Household and yard rubbish is often burned in yard incinerators because it is easier and less offensive aesthetically than to store large amounts of refuse until the regular collection day. Some garbage and rubbish is

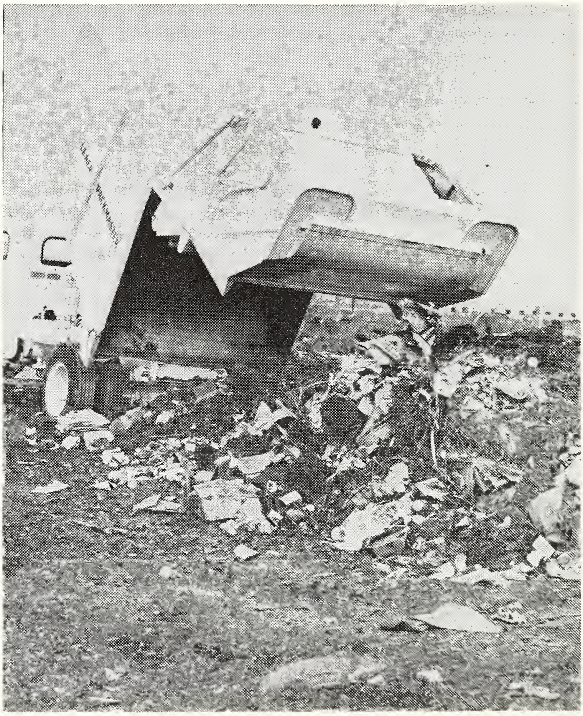

Fig. 10. Household refuse is a heterogeneous mass that is extremely difficult to separate after it has been collected together.

also burned in apartment building incinerators, mainly because of convenience. Consequently, in some cities the amount of combustible refuse collected is relatively small.

The amount of reclaimable material salvaged from household or business refuse is closely related to the market value of the materials. In fact, the proportion of rubbish in refuse is often considered an index of general prosperity. For example, when waste paper can be sold for even as little as $4 a ton, large amounts will be salvaged by householders and stores and relatively small quantities will be collected as rubbish. Similarly, scrap metal, bottles, rags, bones, and other materials are sold when there is a demand for them by junk dealers. At such times the quantity of refuse collected is considerably less than when the value of salvage material is small. Then it is not ordinarily worth while to separate it from other refuse, and large quantities must be collected by the regular forces. Scavengers, when permitted, often pick up part of the refuse that has been put out for collection. Civic and charitable organizations also collect some kinds of salvage materials.

Some garbage (so-called "swill"), especially that from hotels and restaurants, is valuable as hog feed, and therefore it is frequently sold to hog farmers, even if the city collection agency would collect it without charge. Hog raisers take a large part of the commercial garbage of some cities, thus substantially reducing the amount collected by the regular collection agency. However, since the trend has been for farmers to charge for removing garbage, there is more demand for municipal collection and disposal of commercial garbage.

The administrator of a refuse collection and disposal agency ordinarily is concerned only with the amount of waste material he has to handle. He can determine this amount by day-to-day measuring or it can be estimated on the basis of experience in similar jurisdictions.

In many large cities, the city collects only from 50 to 75 per cent of the refuse that is handled at disposal points. It is usually not possible, however, to accurately determine the amount of refuse that is salvaged.

Table 4, based in large part on scaled weights, shows the differences in the amounts of refuse produced, collected, and disposed of in New York City. The differences, although not necessarily typical of other cities, emphasize the need for study and appraisal of local conditions when planning a municipal disposal system. Although the total refuse produced, exclusive of that which is self-disposed of, is 4.54 pounds per capita per calendar day, if all solid wastes produced were included (ashes from power plants; crates, paper, and other specialties from manufacturers; and plaster and rubble from demolition contractors) the per capita amount would be substantially larger. The amount actually collected by municipal forces and by others totals only 3.44 pounds per capita per calendar day, or about 75 per cent of that produced; and the amount disposed of is only 3.08 pounds, or about 68 per cent of that produced.

A project was begun in 1958 at Purdue University (later supplemented by work of the APWA Refuse Disposal Committee and by the United States Public Health Service) to develop techniques of physical and

Table 4

REFUSE PRODUCED, COLLECTED, AND DISPOSED OF, NEW YORK CITY, 1959-1960, IN TONS

Collected by Department of Sanitation				*Collected by Private Cartmen*			*Handled by Private Industry*		*Handled by Federal and State Agencies*	*Totals*	
										Tons	*Pounds per Capita per Day*
					PRODUCED						
Garbage and rubbish 2,287,000	Garbage and rubbish burned in domestic incinerators. (Only 163,000 tons residue col.) 739,000	Ashes (about 10% collected separately for sale; balance col. with garbage and rubbish) 250,000	Grit and screenings from Dept. of Pb. Wks. sewage treatment works 40,000	Garbage and rubbish 1,250,000	Ashes (about 50% col. separately for sale; balance col. with garbage and rubbish) 500,000	Swill (col. separately for disposal at piggeries) 37,000	Burnable construction wastes (90% self-disposed of by on-site burning) 1,140,000	Fats, bones, animals, etc. (col. and disposed of by mfg. of fertilizers, etc.) 227,000	168,000	6,638,000	4.54
					COLLECTED						
Garbage, rubbish, unseparated ashes, and domestic incinerator residue 2,628,000	Separated domestic incinerator residue 47,000	Separated ashes (sold) 25,000	Grit and screenings from Dept. of Pb. Wks. sewage treatment works 40,000	Garbage, rubbish, unseparated ashes 1,500,000	Separated ashes (sold) 250,000	Swill 37,000	Burnable construction wastes (about 10% of total produced in city) 114,000	Fats, bones, animals, etc. (col. for mfg. of glues, oil, fertilizer, etc.) 227,000	168,000	5,036,000	3.44
					DISPOSED OF						
Garbage, rubbish, unseparated ashes, and domestic incinerator residue 2,628,000	Separated domestic incinerator residue 47,000		Grit and screenings from Dept. of Pb. Wks. sewage treatment works 40,000	Garbage, rubbish, unseparated ashes 1,500,000			Burnable construction wastes 114,000		168,000	4,497,000	3.08

chemical analysis of refuse that would be useful in the design of refuse collection and disposal systems. Some of the results of this study, giving methods of analysis, are in Appendix A.

APWA Refuse Studies

Knowledge of the amount and characteristics of refuse in a city is basic to the design and satisfactory operation of refuse disposal facilities and the application of refuse disposal methods. Data gathered through questionnaires have more or less successfully delineated, on a broad basis, the quantities of refuse collected and disposed of in cities across the country. The interpretation of these data and the application of them to engineering design problems have been seriously hampered, however, because of the heterogeneous local practices reported, as well as the unreliability of some of the data because of conflicting definitions of terms and incomplete or inaccurate reporting.

The development of this manual was dependent in part on the availability of data on the quantity of refuse that were reliable. The APWA Committee on Refuse Disposal thought on-the-spot collection of data on a standardized basis in representative cities was necessary. It is the committee's intention that the data obtained in this survey supplement the material in Refuse Materials, Chapter 2 of *Refuse Collection Practice.*

Twelve cities of wide geographical and climatic distribution and with populations ranging from 4,500 to 8 million were selected for the on-the-spot survey. Consideration was also given to the quality and completeness of data given in questionnaires previously answered by these cities for APWA.

To insure standard techniques, the study was conducted in each of the 12 cities by the committee secretary in 1959.

The data, the results of this on-the-spot survey, while representing the most reliable information obtainable at the time, should not be used to solve specific problems. Rather, they should be used as guides to solutions.

Total Refuse Collected

Table 5 lists the 12 cities in which the surveys were made in the order of the total quantity of refuse collected. In only three cities—Chandler, Arizona; Garden City, New York; and Hartford, Connecticut—were complete records kept on the weight of all refuse disposed of by the city agency. In New York and Los Angeles assigned truck weights, based on sample weighings, are used. San Francisco is the only city of the group in which householders and commercial establishments are charged on the basis of the amount of refuse collected. Collection rates in San Francisco are determined by the number of containers used and the frequency of collection. In the 11 other cities all reasonable amounts of refuse are collected, regardless of whether the collection system is financed by service charges or general taxes.

In determining the maximum, minimum, and median quantities of refuse collected in the cities studied, San Francisco is not included. It is listed in the table only to show that smaller amounts of refuse can be expected for collection if charges to the householder are based on quantity.

The largest quantity of refuse collected in the 11 cities is in St. Petersburg, Florida. It is 53 per cent greater than that collected in Cincinnati, the city with the smallest amount. This range from minimum to maximum is notably smaller than that found in former questionnaire surveys made by APWA. (The maximum was more than 200 per cent greater than the minimum in some of those surveys.) Likewise, the range between the median in Hartford and the maximum in St. Petersburg is only 18 per cent, compared to as much as an 80 per cent difference in the maximum and median values reported in earlier surveys.

Of particular interest is the median figure for the quantity of refuse collected. This figure of 1,430 pounds per capita per year in Hartford was arrived at by actually weighing all refuse, and Hartford is one of only three cities in the survey group that did so. The other two cities in which accurate weights were kept on all refuse are Garden City, which produced 1,438 pounds per capita per year, and Chandler, which

Table 5

TOTAL REFUSE COLLECTED IN 12 UNITED STATES CITIES, 1957-1958[1]

City	*Pounds per Capita per Year*	*Pounds per Capita per Day*
St. Petersburg, Florida	1,690	4.63
Los Angeles, California	1,677	4.61
Washington, D. C.	1,638	4.36
Chandler, Arizona	1,587	4.35
Garden City, New York	1,438	3.94
Hartford, Connecticut	1,430	3.92
Seattle, Washington	1,370	3.75
Omaha, Nebraska	1,370	3.75
New York, New York	1,325	3.63
Atlanta, Georgia	1,252	3.43
Cincinnati, Ohio	1,103	3.03
San Francisco, California[2]	794	2.18

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[1] Includes refuse actually collected, regardless of the method of collection or disposal. It does not include automobile bodies, cinders, and bones and fats; since they are usually salvaged before collection and sold, they cannot be considered wastes. Apartment house incinerator ash is calculated in terms of equivalent amounts of refuse.

[2] San Francisco is set apart from the other 11 cities because it is the only one in which the householder is charged for refuse collection on the basis of quantity. The method of charging is an incentive for the householder to dispose of as much refuse as possible on his premises. Thus the figure for the amount collected is much lower than it is in other cities.

produced 1,587 pounds per capita per year. For the other cities, some of the figures are based on partial weighing and partial estimates, while others are entirely estimates. In estimating quantities, of course, some estimates are higher and some are lower than the actual amount. It is interesting, therefore, to find that in the three cities in which accurate weight records are kept the amounts of refuse collected vary less than 10 per cent and that one city, Hartford, has the median value in the table, which theoretically is the average for the group.

Geographical Differences. The survey does not show a clear-cut difference in total amounts of refuse collected by cities in various geographical locations. There are, however, wide differences in the amounts of various components in refuse between northern and southern cities. Yard or garden rubbish and ashes are the two best examples.

In most of the country the season for yard rubbish is from April or May until November or December, with exceptionally large quantities in the early months of the period—the annual clean-up time. In the northern part of the United States there is no yard rubbish at all during the winter months. In the regions that have a mild climate, however, yard rubbish is produced throughout the year, with the peak amount usually in early spring.

The quantity of ashes resulting from the burning of solid fuel for heating is directly related to the severity of the weather. It is obvious that ash output from burning solid fuel is less in Florida or southern California than it is in the New England states. With the increasing use of liquid and gaseous fuels for heating, however, this difference is diminishing, as is shown later in this chapter.

Before the days of mass communication and rail transportation there were areas of the country in which for the most part only people of a single nationality lived. They often adhered to native customs in family and social life and were thrifty according to nationality patterns, which undoubtedly influenced the quantity of refuse they produced. Moreover, most people had to use only the foodstuffs that were produced locally.

Today, because of nationwide radio, newspapers, and magazines, people in one area are much like those in others, in their family and social life and in their recreational activities. A family in Texas reads much the same magazines, wears many of the same brands of clothes, and discards the same kinds of toothpaste tubes as a family in Oregon or Pennsylvania.

A head of lettuce picked in California on Monday can be eaten in Boston the following Friday, a lobster from Boston can be served in Omaha the day after it is caught. Rapid transportation and mechanical refrigeration make it possible for supermarkets in Wyoming to stock the same foodstuffs the supermarkets in Maryland do. The same nationally advertised brands of canned pears can be found coast to coast.

As part of this similarity in living habits, people discard similar types and quantities of refuse in all regions of the country. Differences in collection practices, disposal regulations, and the manner in which the refuse is disposed of (sometimes partially on the premises) account for what appear to be wide differences in quantities of refuse disposed of by municipal agencies in various parts of the United States.

Seasonal Differences. The extent of seasonal variations in the quantities of refuse produced in a municipality is important, for a variety of reasons, to officials responsible for refuse disposal. A disposal operation must be designed to take care of peak loads. Additional personnel are usually required during the season of high refuse production, and regular employees must often work overtime. By anticipating these labor requirements and hiring additional personnel in advance of actual need, the disposal system can operate smoothly and economically in the rush season. Employees can take leave and equipment can be repaired and major plant maintenance work done during the slack months.

The amounts of refuse for each season must be determined on the basis of each city's own records, since the pattern of change may differ drastically among cities.

There are several factors besides climate that influence seasonal changes. Most important are the type of fuel used for heating; the amount of vegetation within a city—lawns, trees, and shrubs on private property and along streets and in parks; construction work; and the abundance of fresh fruits and vegetables. In some cities, an important influence on seasonal variations is the number of tourists. This is particularly true in some small resort areas where the population may increase tenfold during "the season." Advance planning for refuse disposal based on past experience of seasonal differences is especially important in these instances.

Figure 11 compares the seasonal variations in the amount of refuse incinerated in Hartford and Cincinnati. The season of highest refuse production in both cities is in the warm months, but the pattern for each city is different.

In Hartford there is an annual spring clean-up campaign, which accounts in part for the high production in April and May. Hartford is a city abounding in trees so that in the autumn great quantities of leaves are collected and incinerated. The second peak shown on the graph reflects the leaf pick-up time in September or October. The below-average production of refuse in July and August in Hartford occurs each year and is thought to come about because many of the large number of white collar workers in the city are vacationing away from the city during these months.

The seasonal pattern of refuse production in Cincinnati is probably more typical of American cities that do not have annual spring clean-up campaigns. It reflects normal increases in summer activities such as gardening, house cleaning, and construction.

Daily Differences. To the municipality that collects refuse weekly, variations in daily refuse production are not as important as they are to cities that give more frequent service. If refuse is collected weekly, the concern is only with fluctuations from week to week, since the length

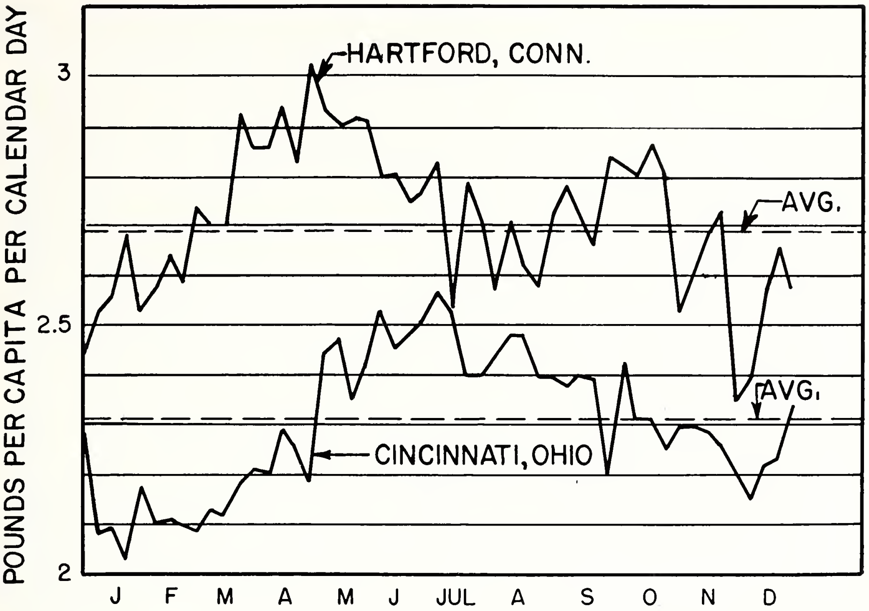

Fig. 11. Seasonal differences in amounts of refuse incinerated in Hartford, Connecticut, and Cincinnati, Ohio, 1957.

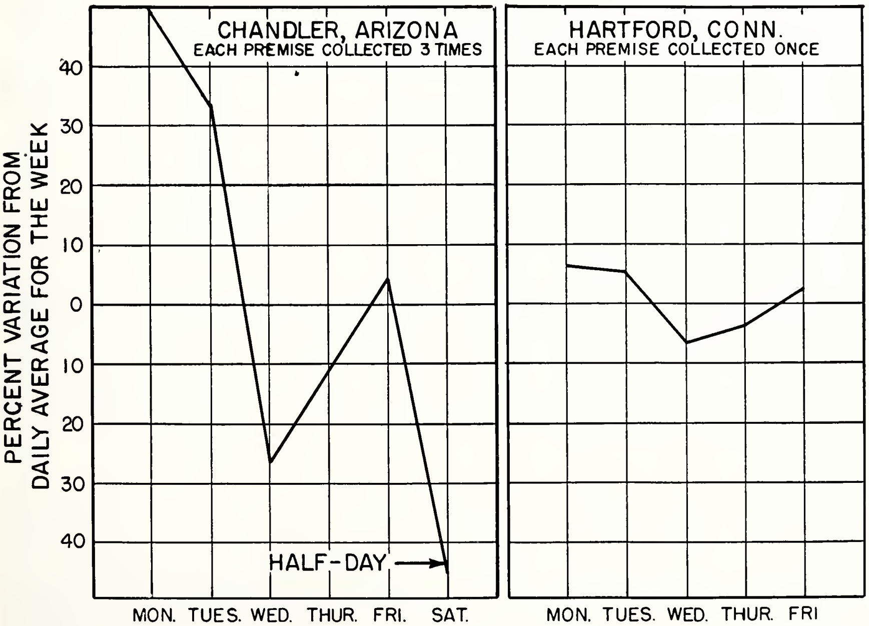

Fig. 12. Comparison of quantities of refuse collected during typical weeks in Chandler, Arizona, and Hartford, Connecticut.

of the routes covered on high collection days, such as Mondays, can be shorter than the routes followed on days of low production.

If refuse is collected twice a week or oftener, the quantities collected will vary greatly each time. For example, if a route is serviced on Mondays and Thursdays, the amount of refuse collected on Mondays may be double the amount picked up on Thursdays. The reasons are obvious: most housewives do their weekly marketing on Thursdays, Fridays, or Saturdays—after the Thursday pick-up—which means more greens, packages, and bottles in the refuse; more yard work is done on weekends; and there is a four-day accumulation of refuse on Mondays and only a three-day accumulation on Thursdays. The weather also influences the daily output of refuse. If the weekend weather is unusually good there will be far greater quantities of refuse on Monday than if the weather is bad.

Figure 12 shows the daily variations in amounts of refuse in a city that collects three times a week, compared with amounts in a city that collects only once a week. The graph shows that if refuse is allowed to accumulate for a week or longer, variations in amounts collected each day average out and the fluctuations are usually not noticeable. But if collections are more frequent, the differences are more apparent. Daily differences in quantities of refuse are extremely important to the administrator of disposal facilities that are not flexible enough to handle widely varying amounts.

Component Quantities and Their Variations

Up to this point only total refuse quantities and how those quantities are affected by geography and periods of time have been discussed. But the different components of refuse and their quantities and variations are also important.

Insofar as possible, data from the 12 survey cities are used. In some instances, however, it is necessary to use examples from *Refuse Collection Practice* and other survey data for the sake of completeness.

Many cities collect all kinds of refuse together, particularly if dumping or sanitary landfill is the method of disposal. In fact, there has been a marked trend toward combined collection in recent years, primarily for economic reasons. Other cities require the separation of refuse into two, three, or even four categories, depending almost entirely on the methods used for disposal. There are also cities that collect garbage alone, rubbish alone, ashes alone, ashes and rubbish together, garbage and combustible rubbish together, and ashes and noncombustible rubbish together.

Garbage. Only two of the cities in which the quantity survey was conducted collect garbage separately. Los Angeles collects garbage from all residences, restaurants, and hotels at the rate of 129 pounds per person per year by actual weight. Washington, D.C., collects garbage from all residences and from about 20 per cent of the commercial establishments at the rate of 117 pounds per person per year by actual weight. An additional estimated 93 pounds per person per year is collected by private

Table 6

QUANTITIES OF REFUSE COLLECTED IN 12 UNITED STATES CITIES, 1957-1958[1]

(By categories as defined by each city)

	Lbs. per Capita per Year
St. Petersburg, Florida; estimated population served, 154,000	
City collected garbage (wrapped food, wastes, bottles and cans used as food containers, paper, rags, cartons)	1,037***
City collected trash (mostly yard rubbish)	91***
Privately hauled to landfill (all kinds of refuse taken by commercial trucks and passenger cars)	562***
Dead animals — 94 per 1,000 pop. per year	
Total	1,690
Los Angeles, California; estimated population served, 2,370,000	
City collected garbage (food wastes)	129*
City collected noncombustible rubbish	135*
City collected combustible rubbish	568**
City collected dead animals — 154 per 1,000 pop. per year	
Privately collected rubbish (commercial, demolition, and industrial refuse)	845***
Total	1,677
Washington, D. C.; estimated population served, 860,000	
City collected garbage (food wastes)	117*
Privately collected garbage (food wastes)	93***
City and privately collected ashes and noncombustible rubbish from households, government buildings, street cleaning, catch basins, commercial and industrial buildings)	647***
City and privately collected trash (household, commercial, and industrial rubbish; street litter)	781*
Dead animals (small only) — 44 per 1,000 pop. per year	
Total	1,638
Chandler, Arizona; estimated population served, 4,500	
City collected residential refuse (garbage, yard rubbish, small household items)	750*
City collected rubbish (from parks, commercial buildings, residences)	837*
Total	1,587
Garden City, New York; estimated population served, 23,060	
City collected garbage (food wastes, paper, paper cartons, barrels, boxes, bottles, tin cans, rags	1,040*
City collected rubbish (yard wastes, furniture, metal)	327*
Privately collected rubbish	23***
City collected ashes	48*
Total	1,438

Table 6 (continued)

		Lbs. per Capita per Year
Hartford, Connecticut; estimated population served, 186,000		
City collected combustible refuse (including garbage)		596*
City collected noncombustible rubbish		28*
Privately collected combustible refuse		428*
Privately collected noncombustible refuse		317*
Privately collected garbage (food wastes)		33***
Scavenger salvage before collection (rags, paper, metal)		28***
Total		1,430
Seattle, Washington; estimated population served, 575,000		
Contract collection of combined refuse		1,148***
Private vehicles (all kinds of refuse)		222***
Total		1,370
Omaha, Nebraska; estimated population served, 299,000		
Contract collection of combined refuse		459***
Private vehicles (combined refuse)		612***
Privately collected noncombustible refuse		267***
Private paper salvage		32***
Total		1,370
New York, New York; estimated population served, 8,500,000		
City collected burnable garbage and rubbish		377**
Privately collected burnable garbage and rubbish		236**
City collected unburnable garbage and rubbish		120**
Privately collected unburnable garbage and rubbish		75**
City collected ashes		256**
City collected domestic incinerator ash (in terms of equivalent refuse)		106**
Other refuse to private disposal		77***
Privately collected swill		52***
Privately collected construction wastes		14***
City and federal agency refuse		12**
Total		1,325
Atlanta, Georgia; estimated population served, 560,000		
City and privately collected garbage (food wastes, paper, cans, bottles, general household wastes, rubbish)		1,104[2]
City collected street sweepings and other debris		123***
Privately collected swill (food wastes)		25***
Dead animals	73 per 1,000 pop. per year	
Total		1,252
Cincinnati, Ohio; estimated population served, 547,800		
City collected combustible refuse (garbage, rubbish)		545*
Privately collected combustible refuse (garbage, rubbish)		297*
City collected noncombustible rubbish		129***
Privately collected noncombustible rubbish (commercial, industrial)		132***
Dead animals	48 per 1,000 pop. per year	
Total		1,103

Table 6 (continued)

	Lbs. per Capita per Year
San Francisco, California; estimated population served, 800,000	
Privately collected garbage and rubbish	643*
Street cleanings and sewage grit	47***
Private company salvage	104
Total	794

[1] All data are for 1957-1958 except for Chandler, Arizona, which are for 1954.

[2] Of total, 254 pounds were estimated on basis of sample weighing; 850 pounds were actually weighed at permanent weighing stations.

*Weighed.

**Estimated on basis of extensive sample weighing.

***Estimated.

licensed collectors in Washington, for a total of 210 pounds per person per year. The wide disparity between Los Angeles and Washington may be accounted for in large measure by the difference in the number of household garbage grinders in use: in Los Angeles, approximately 1 for each 8 persons; in Washington, approximately 1 for each 50 persons.

Results of a questionnaire survey of 85 cities in 1955 indicated a median of 148 pounds of garbage per capita per year collected, with a range of 74 to 263 pounds. Assuming that this median for garbage collection is representative and comparing it with the median for total refuse collected in 12 cities (see Table 5), it can be concluded that the garbage content of the total refuse averages about 11 per cent by weight. However, if a comparison is made with a mixture of garbage and rubbish only, the garbage content will be approximately 20 per cent by weight.

Factors that influence yearly quantities of garbage collected are (1) thoroughness, (2) frequency, (3) transient population, (4) degree of home disposal, and (5) elective service. Accuracy of records, of course, affects the quantities reported.

Seasonal differences in amounts of garbage are quite pronounced. The peak is usually in mid-summer when fresh vegetables and fruits are plentiful throughout the country. Corncobs and husks, melon rinds, and other fruit and vegetable wastes add greatly to the load during this period. The increase ordinarily begins in May and reaches a peak in August; by October collections are again down to normal.

A few cities do not follow this pattern of monthly differences but reflect radical seasonal changes in population. They are summer or winter resort cities or cities that temporarily lose many of their residents to resorts.

The trend toward combined collection of garbage and combustible rubbish or combined garbage and rubbish makes it difficult to get information on the amount of garbage collected. However, the amount of garbage collected undoubtedly will continue to decrease with the increasing use of food waste grinders, semi-prepared vegetables, and conveniently packaged foods that leave little household waste. The decline in home canning of fruits and vegetables also reduces the amount of household garbage.

Rubbish. The trend toward combined collection has reduced the amount of information available on the quantity of rubbish collected, as well as of garbage.

For example, not one of the 12 cities included in the on-the-spot quantity survey had separate complete information on rubbish collection —as "rubbish" is defined in this book. Los Angeles and Washington, D.C., the two cities in which garbage is collected separately, also collect rubbish separately. But there are factors that complicate accurate measurements of rubbish even in these cities.

In Los Angeles the city collects a total of 703 pounds of combustible and noncombustible rubbish per capita per year, but there is an undetermined quantity of rubbish collected by private haulers. This unknown quantity is part of the 845 pounds per capita per year of combined rubbish, commercial refuse, demolition refuse, and industrial refuse collected by private haulers in Los Angeles.

Washington collects a total of 1,257 pounds per capita per year of combustible and noncombustible rubbish from all sources (households, businesses, and government agencies). The inclusion of ashes with noncombustible refuse and the collection of some industrial refuse with trash introduce unknowns.

The situations in Los Angeles and Washington point up the difficulties of getting accurate information on the amount of rubbish, or for that matter on any other single component of refuse. Combined collections plus other factors of collection and separation probably account for the extremely wide range in the amounts of rubbish reported for United States cities in *Refuse Collection Practice*—144 to 1,440 pounds per capita per year.

Fluctuations in the quantities of rubbish in relation to daily, weekly, and seasonal differences and the effect of climate, salvage, and on-site disposal on the quantities are much the same as those for total refuse.

In the United States the trend is toward larger quantities of rubbish because of more yard rubbish from large lots and the increased use of paper and paper products, plastics, wood, and metal foils in packaging. Furthermore, on-site disposal has decreased because of air pollution control regulations and better collection service, which increases the amount of rubbish that must be disposed of by the municipality.

Ashes. Garden City and New York are the only cities in the on-the-spot survey in which ashes were collected separately. In New York, the ash collection (mixed or separated) in 1957 was 256 pounds per capita per year. Garden City produced only 48 pounds per capita of ashes in 1957, compared to 66 pounds in 1955 and 419 pounds in 1939.

The reduction in ash production in Garden City in recent years may not be typical, but there is an undisputed downward trend in the ash content of refuse in cities of the United States. The increasing use of more fuels for cooking and heating that do not produce ash is the principal reason for this marked trend.

In those cities in which ash producing fuels are still in wide use, the ashes are sometimes put to use for cover and access roads on landfills. Separate collection of ashes is made in some cases.

The climate obviously influences the quantity of ashes produced in a city. Northern cities produce more than southern cities, and, of course, most of the ashes are produced during the winter. Figure 13 shows these variations in Garden City.

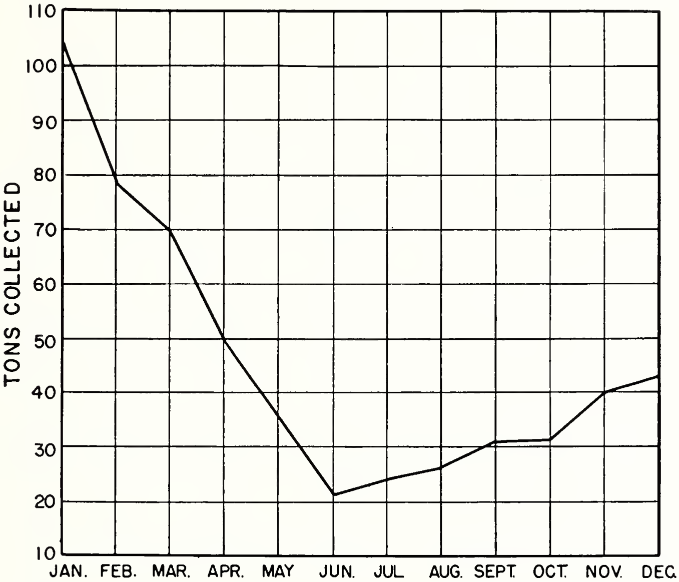

Fig. 13. Monthly differences in amounts of ashes collected in Garden City, New York, 1957.

As the standard of living continues to rise in the United States, more ashless fuels will be used and the need for ash collection may soon be eliminated entirely.

Rubbish and Ashes Together. All of the factors given earlier that account for variations in the quantity of rubbish collected separately and the quantity of ashes collected separately are equally applicable when these two refuse components are collected together.

In Washington, D. C., where ashes are collected with noncombustible rubbish, a total of 506 pounds per capita per year was collected in 1957 from households, government buildings, and commercial and industrial establishments.

A 1956 APWA survey, as reported in *Refuse Collection Practice,* showed a median of 630 pounds of rubbish and ashes per capita per year, with a range of 532 to 900 pounds per capita per year in cities where rubbish and ashes were collected together.

There are three important points to be remembered about collecting rubbish and ashes together (assuming the combination is compatible with the disposal methods used). First, the volume of the combined material will be only slightly more than the volume of the rubbish alone, since ashes tend to fill the voids in the rubbish. Second, there is always danger of fire when ashes are combined with combustible materials. Many fires have been started in collection vehicles and in landfills by ashes that apparently were cool and completely extinguished. Third, since ashes are largely noncompactible, the compaction device on compactor-type trucks must be constructed ruggedly to withstand greater abrasion than for other types of compaction.

Garbage and Combustible Rubbish Together. Combined collection of garbage and combustible rubbish is frequently found in cities that use incineration as a means of disposal. Seven of the survey cities have incinerators and six of them collect these components of refuse together.

Quantities of garbage and combustible refuse in these six cities ranged from 719 to 1,104 pounds per capita per year, with a median of 1,032 pounds per capita per year. The median for the garbage and combustible refuse is 78 per cent of the median of the total refuse produced in these six cities. These data are presented in Figure 14.

Here again, the factors that account for quantity variations—among cities and periodic fluctuations within a specific city for separate refuse components—can be applied when the components are collected together.

If incineration is used for disposal of garbage and combustible refuse together, it is essential that the degree and frequency of these fluctuations be known for this category of refuse. By anticipating the periods of high and low production of the materials to be burned, incinerator operation and maintenance can be planned more intelligently.

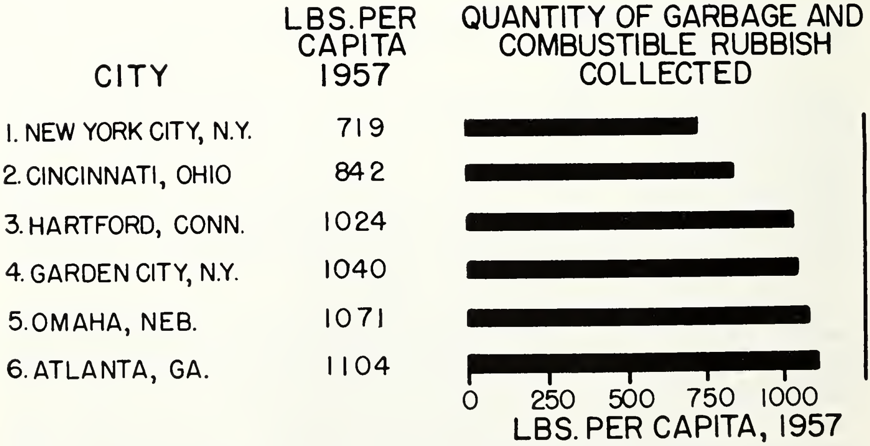

Fig. 14. Quantities of garbage and combustible refuse collected in six United States cities, 1957.

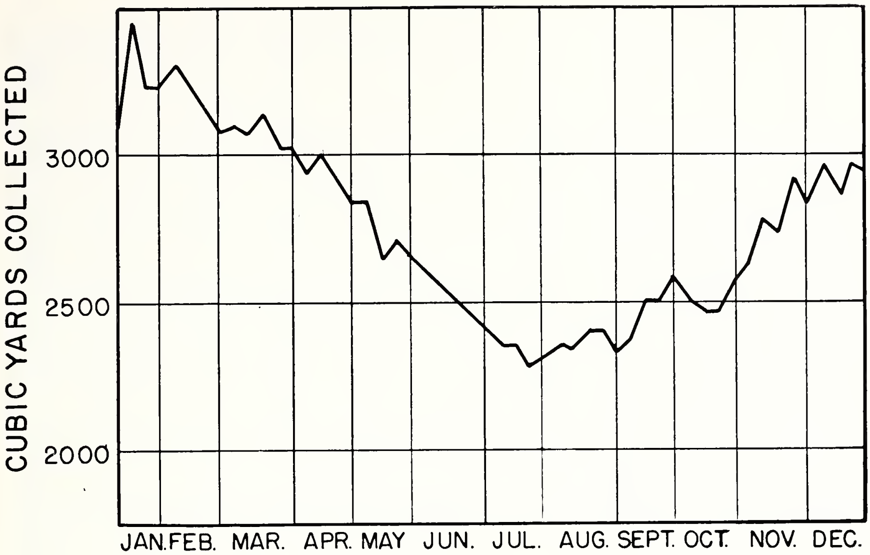

Fig. 15. Comparison of weekly collections of noncombustible rubbish in Cincinnati, Ohio, 1957.

Noncombustible Rubbish. None of the 12 survey cities required complete separation of all noncombustible rubbish (as defined in this manual) from all sources. In some cities, ashes are included in this category; in others, ashes are collected separately but bottles and cans are, by local definition, considered garbage. Some cities classify as noncombustible items that are too large for the incinerator, although they actually are combustible.

Since back yard burning was banned in Los Angeles in 1957, ashes have been almost entirely eliminated from noncombustibles. Except for some noncombustibles from commercial and industrial establishments, which are privately collected and disposed of, "noncombustible refuse" in Los Angeles closely approximates the definition for it in this manual. About 135 pounds per capita per year of noncombustible rubbish were collected in Los Angeles in 1957-1958.

Figure 15 is a graphic comparison of the amounts of noncombustible rubbish collected in Cincinnati each week.

The principal reason in the past for requiring separation of noncombustible rubbish from combustible components was incinerator design. The large, modern incinerators in use today do not require much separation, however, except for large quantities of ashes and bulky objects, which is the reason that many cities include cans, bottles, ceramics, and other noncombustibles in their defininition of garbage or combustible refuse. In cities that use sanitary landfill as the method of disposal, there is, of course, no separation of the refuse components.

Dead Animals. The number of dead animals collected and disposed of by municipal refuse agencies varies with the extent and effectiveness of the service offered. If complete collection is made—that is, from private property as well as from city streets and also upon request of residents—nearly all animals that die in a city are collected by the city refuse disposal agency. In other cities many small animals are disposed of by individuals.

Five of the survey cities provided data on the number of dead animals collected and disposed of. Washington, D. C., disposes of 44 animals per 1,000 population each year; Cincinnati, 48; Atlanta, 73; St. Petersburg, 94; and Los Angeles, 154. In New York, where dead animal collection is under contract, there are only 14 collected per 1,000 population. Table 7, which emphasizes the extensive collection service offered by Los Angeles, gives the kinds and numbers of dead animals collected in fiscal 1956-1957.

The number of dead animals fluctuates seasonally, with more in the summer than other times of the year.

In most cities, disposal of small animals does not pose a major problem They can be incinerated or buried in a sanitary landfill.

Table 7

NUMBER OF DEAD ANIMALS COLLECTED BY SPECIAL COLLECTION SERVICE, LOS ANGELES, CALIFORNIA, FISCAL YEAR 1956-1957
(By size and kind)

Kind	*Number*
Small	
Chickens	173,861
Cats	92,692
Dogs	65,586
Rabbits	16,072
Rats	10,883
Guinea pigs	2,924
Others	3,635
	365,653
Medium	
Goats	329
Sheep	319
Deer Heads	142
Calves	99
Seals	65
Hogs	32
Others	11
	997
Large	
Horses	35
Others	26
	61
Total animals	366,711
Total tonnage	1,317

Large animals are effectively disposed of in many cities at local rendering plants, which often offer free pick-up for the privilege of processing the animals.

Street Refuse. Street refuse includes street sweepings, dirt, leaves, catch basin dirt, and the contents of litter receptacles. Collection and disposal of this refuse varies considerably among cities. In some cities, street sweeping and catch basin cleaning, as well as the disposal of the material, are the responsibilities of the street department. However, collection and disposal of leaves and litter is usually the responsibility of the refuse collection and disposal agency.

Divided responsibility within cities, as well as the differences among cities, make it difficult to determine how much street refuse is collected and disposed of.

In the survey of cities, quantities of street refuse collected ranged from 31 to 171 pounds per capita per year. In Hartford, New York, and San Francisco, where leaves are not included, quantities of street refuse are 31, 40, and 47 pounds per capita per year respectively. In Atlanta and Washington, where leaves are included, the quantities are 123 and 171 pounds per capita respectively.

Seasonal differences in amounts of street refuse are quite pronounced. Quantities are affected by accumulations of leaves in the fall, greater littering by the public in the summer, and, in some northern cities, street sanding during the winter. Leaves and street sanding also increase the amount of catch basin accumulations. For a more detailed discussion of street refuse, see *Street Cleaning Practice.*[1]

Industrial Refuse. Wastes from industry for many years were considered the responsibility of the manufacturer. If the wastes were solid, they usually were disposed of in an open dump. Liquids were often dumped into nearby streams.

Anti-pollution measures, for both air and water, as well as fewer dump sites, have influenced a trend toward municipal disposal of industrial wastes. Where industrial wastes are disposed of by a city, they are frequently delivered to a disposal site by the industry and the city usually charges for disposal, according to the quantity and type of material.

There is only one accurate way to determine the quantities of industrial wastes within a city: by conducting a complete survey of all plants. The types of wastes should be determined, as well as the quantities, so that special disposal problems of incineration or landfilling can be anticipated. For example, if a city is planning to build an incinerator for municipal and industrial wastes, the design could be influenced by large quantities of wet wastes, such as paunch manure, and highly inflammable material, such as some plastics. Also, special provisions may be required for flammable materials, such as cleaning fluids.

Demolition Refuse. Sixty-four cities of more than 100,000 population, responding to a survey of disposal practices in cities in the United States made by the APWA in 1958, revealed the following:

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[1] American Public Works Association, Street Sanitation Committee, *Street Cleaning Practice* (Chicago: Public Administration Service, 1959), 424 pp.

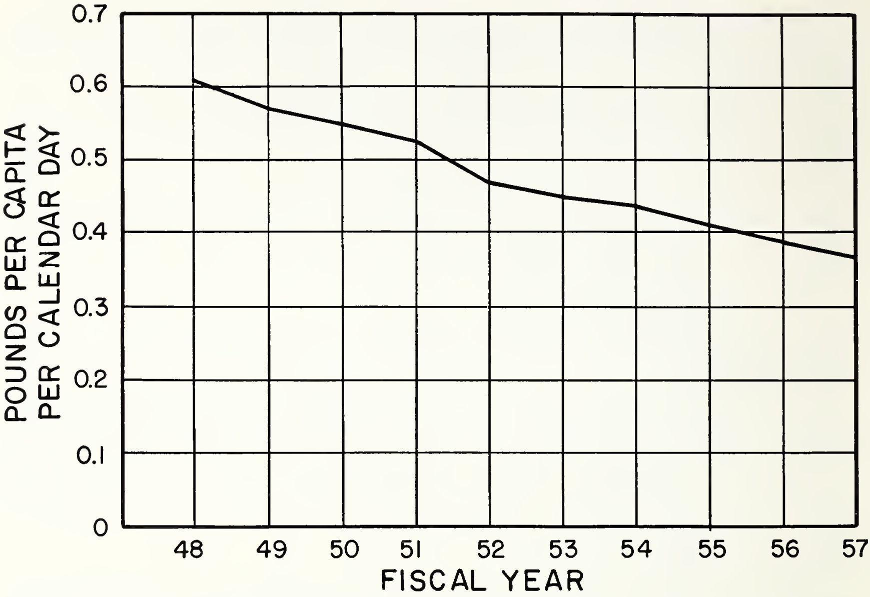


Fig. 16. Ten-year summary of amounts of garbage collected in Los Angeles, California, 1948 to 1957.

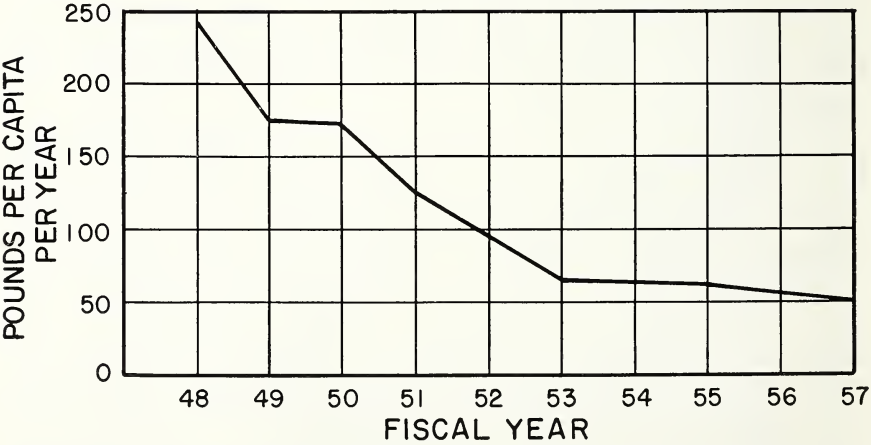


Fig. 17. Ten-year summary of amounts of ashes collected in Garden City, New York, 1948 to 1957.

1. In more than one-fourth of the cities the final disposal of demolition refuse is a municipal responsibility. Most cities charge for it.
2. About three-fourths of the cities reported that they dispose of demolition refuse by landfill or by burning and landfill. Other methods

> used are burning and open dumping. Six cities use incineration. More than 90 per cent of the cities prohibit on-site burning.

The quantity of demolition refuse is, of course, directly related to the amount of demolition work done in a city. The amounts of refuse to be disposed of vary slightly, even for a single type of structure, according to the amount of salvage practiced.

An estimated total of 2,223,000 tons of demolition refuse were produced in 1957 by 46 reporting cities with a combined population of 29,551,000.

Several large cities, including New York and Philadelphia, have explored the feasibility of using mechanical shredding devices to convert demolition refuse into a form suitable for incineration.

Large, Bulky Refuse. Large, bulky objects, particularly beds, mattresses, divans, chairs, and kitchen appliances, present problems in routine collection and disposal. Some cities, such as New York, provide special collection vehicles for such objects. The trucks are routed according to requests from householders. The material is normally disposed of at landfills. In the fiscal year 1958-1959, New York collected about 32,000 loads of this bulky material, which weighed an estimated 70,000 tons.

Effects of Collection Methods on Disposal

There are considerable differences among cities in the amount of refuse produced, the amount collected, and the amount actually disposed of by the city. Various combinations of city, city-private, and private systems are used for disposal, as well as for collection. Two cities may produce the same per capita quantity of refuse but the amount collected and disposed of in each city by municipal forces may differ widely.

In Garden City, New York, and Chandler, Arizona, the city governments are responsible for collection and disposal of all refuse produced within their limits, with the minor exception of 23 pounds per capita per year of rubbish collected by private haulers in Garden City.

In St. Petersburg, the city disposes of all refuse, but about one-third of it is collected by private haulers. Similar systems are used in Omaha and Cincinnati.

Atlanta, Hartford, New York, and Washington, D. C., dispose of nearly all refuse collected within their limits, except garbage used for hog-feeding and some other minor exceptions. There are, however, varying amounts of refuse collected by private haulers in these cities.

Seattle has a contract collection system but disposal facilitites are operated partially by the city and partially under contract. About 15 per cent of the refuse produced in Seattle is collected by private haulers.

Nearly half of the refuse produced in Los Angeles is collected and disposed of by private licensed contractors. In addition, some combustible rubbish collected by the city is disposed of at private facilities and all of the garbage collected by the city is sold to hog feeders. Practically all noncombustible refuse collected by the city forces is sold under long-term contract to a salvage company.

In Atlanta and Omaha, tin cans from incinerator residue are sold as salvage, thereby eliminating a substantial volume of material.

San Francisco is unique among the survey cities in that it has no direct refuse collection or disposal responsibility. All refuse is collected by two private scavenger associations. Uniform rates are controlled by the city government and charges are collected by the truck drivers from the householders. As pointed out previously, charges are based on the quantity of refuse collected so that there is a strong incentive for householders to dispose of as much refuse on their premises as possible.

Disposal of refuse in San Francisco is in privately owned and operated landfills. The collection associations pay for disposal according to the weight of refuse. Extensive salvage is practiced in San Francisco. Truck drivers separate salvageable items during collection and drop them off at a depot before going to the disposal area.

Per Capita Quantities

Knowledge of the trends over the past years in the per capita quantity of refuse produced and collected is of great value in planning collection activities and equipment and in planning, financing, and construction of disposal facilities. Various factors increase or decrease the total amount of refuse and the amount of certain types and combinations of types of refuse collected from year to year. The increasing demand for more extensive and better collection service has been pointed out by numerous authorities. Social and economic conditions affect the amount of refuse produced, the amount salvaged, and the amount collected. It is evident that extensive use of canned and packaged frozen foods has caused a per capita increase in the amount of rubbish produced (tin cans, boxes, wrappings, and cartons), while the quantity of garbage has decreased. On the other hand, better transportation facilities for fresh foods have probably increased the amounts of garbage in the winter months in some regions. The effectiveness of the refuse collection system may also help modify the amount collected.

Generally speaking, there is a definite downward trend in the total quantities of garbage and ashes collected separately. Conversely, there has been a definite upward trend in the quantity of total refuse collected. Los Angeles, for example, reported that the quantities of garbage collected between 1948 and 1957 decreased from more than 0.6 pounds per capita per calendar day in 1948 to less than 0.4 in 1957 (Figure 16). The quantity of ashes collected by Garden City during the period 1948 through 1957 decreased from about 250 to 50 pounds per capita per year (Figure 17).

Cincinnati is another city that shows a marked decrease in the volume of noncombustibles collected. During the past 20 years, and particularly since World War II, the amount of noncombustibles collected has declined from a high of 720 to 260 cubic yards per capita per year. On the other hand, the amount of combustibles collected has increased fairly steadily over the same period—from almost 380 to 550 pounds per capita per year, or an increase of some 45 per cent for the period.

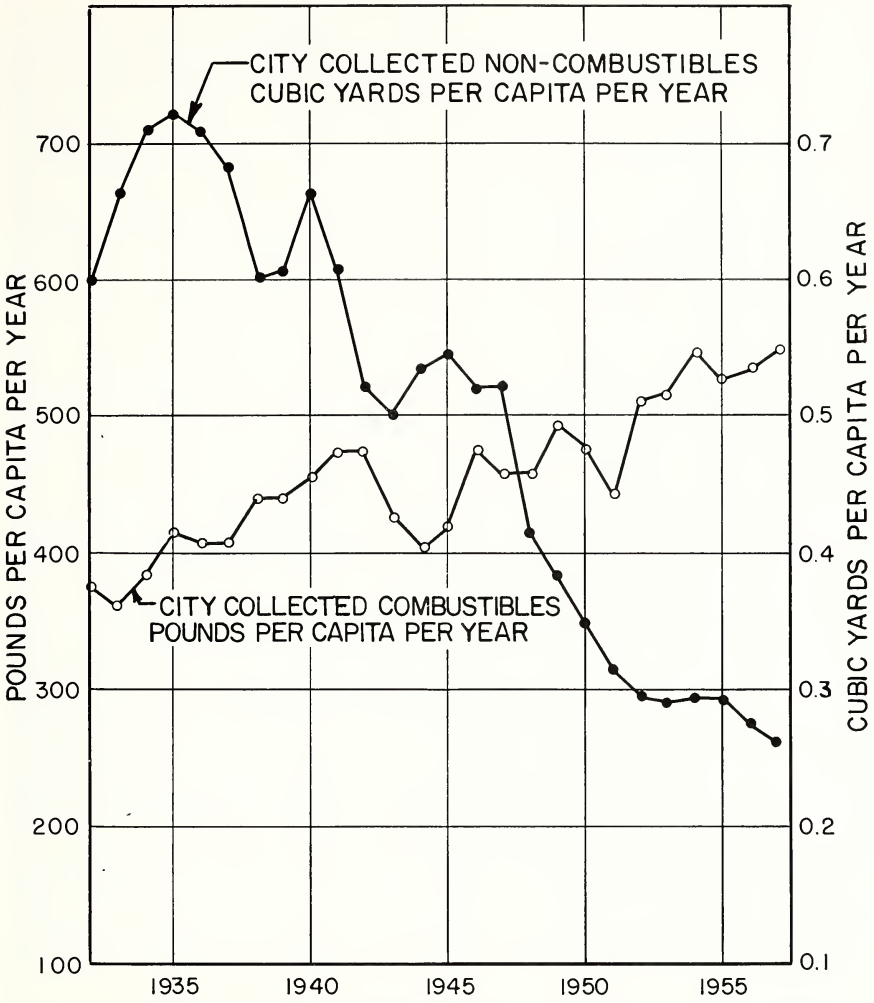


Fig. 18. Yearly fluctuations in quantities of combustibles and non-combustibles collected by city forces, Cincinnati, Ohio, 1932 to 1957.

Unit Weights

Accurate knowledge of the weight of a cubic yard of refuse or the relative density of the material collected and disposed of is valuable for administrative purposes. It is necessary, for example, to know the unit weight of refuse before designing incinerators or planning sanitary landfills. Usually unit weights are determined by each city by weighing known volumes of refuse. For some purposes, however, it may be desirable to compare the weight per cubic yard of certain categories of refuse with similar categories in other cities. Therefore, data are presented here for the more common categories of refuse. When interpreting these data, it is particularly important to consider that refuse is almost always weighed on the collection vehicle, and consequently the type of collection vehicle significantly influences the volume and the unit weight. This is particularly true in determining the volume of rubbish or combined refuse collected in a compactor-type vehicle.

Garbage. The unit weight of garbage is subject to many vagaries. First, there are restrictions placed on the householder through sanitary ordinances and collection regulations. If the householder is required to drain and wrap garbage, the amount of moisture is decreased, which in spite of the added bulk of the paper wrapping will result in a lighter unit weight.

On the other hand, if householders pack the material into containers or if the collectors pack the load, the unit weight increases. Garbage in uncovered containers or open collection vehicles may pick up a substantial amount of moisture during rain, snow, and sleet storms, thus increasing the unit weight. In a 1939 APWA survey, the reported minimum weight of garbage was 798 pounds per cubic yard and the maximum was 1,540, with the average 936 pounds per cubic yard. A similar APWA survey made in 1956 indicated an average of 1,000 pounds per cubic yard for unwrapped garbage collected separately.

Rubbish. Unit weights of rubbish vary widely among cities, depending primarily on what materials a city regularly picks up and what it does not. For example, dry leaves, tree branches, cartons, cans, and similar materials are bulky and if they are not thoroughly packed they weigh little per unit volume. However, leaves, grass cuttings, and all garden rubbish shrink in volume and absorb moisture during decomposition, increasing the weight of the rubbish if it is not collected frequently. Bottles, broken glass, metal, plastics, broken brick, and other construction rubbish and building debris make rubbish much heavier.

The weight of rubbish may range from 60 pounds per cubic yard to more than 600, depending on the separation of materials required and how closely the separations are adhered to in preparing the material for collection.

Ashes. Ashes, if kept dry and free from other types of refuse materials, are quite constant in composition and weight. Added moisture, however, contributes materially to their density. Ashes piled in alleys and back yards during the winter pick up considerable moisture from rain, snow, and sleet. Exposure of open containers to rain, even for a comparatively short time, will affect the weight. In some cities, ashes are purposely moistened to prevent fire from being scattered by the wind during removal. An APWA survey made in 1939 showed that the weight per cubic yard of ashes collected by municipal agencies ranged from 1,150 to 1,400 pounds; the median was 1,250 pounds.

In the 1956 APWA survey, no city reported the amount of ashes collected separately in terms of both weight and volume. It is believed, however, that the median of 1,250 pounds per cubic yard arrived at in the 1939 APWA survey was still accurate in 1956.

Garbage and Combustible Rubbish Together. The reasons for the differences in the unit weights of garbage and rubbish apply also to garbage and combustible rubbish collected together. Indications are that when garbage and combustible rubbish are collected together, the unit weight varies from a minimum of about 200 pounds per cubic yard to a maximum of more than 500 pounds, with the average about 375 pounds.

Rubbish and Ashes Together. The unit weight of rubbish and ashes combined depends in great measure on the proportions in which the two categories are combined, for rubbish is quite light and ashes are quite heavy. The differences in unit weights are more marked if the material is exposed to the weather, either before or during collection, and it absorbs moisture. Data collected in 1939 indicated a range in weight of from 400 to 1,000 pounds per cubic yard, with the average about 700 pounds if ashes are the predominant component. As the amount of ashes in proportion to the amount of rubbish decreases, however, the weight decreases also.

Noncombustible Rubbish. The unit weights of ashes and noncombustible rubbish combined do not vary as widely as those for the other classes of refuse discussed so far. Data available in the late 1950's indicate that unit weights for noncombustible rubbish vary from about 400 to 600 pounds per cubic yard if relatively few ashes are included. The differences in weight can be attributed to the differences in types of coal, the kinds of noncombustible materials included in regular collections, and the amount of moisture in the rubbish.

All Refuse Together. The same reasons for the differences in the unit weights of the various categories of refuse apply also to all types of refuse when collected together. Local collection regulations and practices influence the relative amounts of components in refuse in each community and are, therefore, the most important factors in the weight. The type of collection vehicle used is also important.

The unit weight of all refuse together varies from 300 pounds to nearly 700 pounds per cubic yard; the average is about 350 pounds.

Physical and Chemical Composition of Refuse

Published data on the physical and chemical composition of refuse are meager. Most studies that have been made of the subject have been made to help a city determine what disposal method it should use. They have been done in connection with the design of incinerators, sanitary landfills, and composting techniques. Since different information on the composition of refuse is required for each of these disposal methods, complete analyses are seldom made.

Until recently no effort had been made to develop standard procedures for analyzing refuse. Comparison of analytical results from different municipalities, therefore, was of little value. In the 1958 study at Purdue University referred to earlier, some standards were developed and are included in Appendix A.

Analyses for Incineration

The most important single factor of refuse composition as far as incineration characteristics are concerned is the net calorific value per unit weight. This net value is affected by moisture content and by the ratio of combustible to noncombustible constituents in the refuse.

The moisture content of refuse is made up of bound and free moisture. Large amounts of vegetable matter result in high bound moisture content, although on visual inspection the material may appear dry because of the lack of free moisture. The net calorific value of refuse is reduced by the amount of heat required to evaporate the water present. Other materials that are noncombustible at ordinary incinerator temperatures likewise reduce the net amount of heat available from combustion of a unit weight of refuse. When calculating the calorific value for refuse by components, the paper and food in cans and bottles is usually neglected as having no heat value. Coal ash, when considered as a separate component, neither reduces nor increases the calorific value of the refuse, since it normally contains sufficient heating value to raise its temperature independently of the other combustible material (Tables 8 and 9).

Table 8

CALORIFIC VALUE, MOISTURE, AND ASH CONTENT OF REFUSE, CHICAGO, ILLINOIS, 1956-1957

	Calorific Value (Refuse) BTU/lb.			*Per Cent Moisture (Wet basis)*		*Per Cent Ash in Refuse*
Date	*High*	*Low*	*Average*	*Garbage*	*Refuse*	
3/56	4,810	2,880	3,370	61.0	15.0	37.2
4/56	5,320	3,680	4,280	...	...	...
5/56	4,820	3,200	4,050	...	...	...
6/56	4,600	3,610	4,120	78.6	16.2	38.5
10/56	4,390	3,230	3,790	...	12.1	...
2-3/57	3,590	2,700	3,310	72.3	10.4	48.0
4/57	...	...	3,890	76.4	20.8	25.6
6/57	...	...	...	69.1	18.2	38.2
Average	4,590	3,220	3,830	71.5	15.5	37.5

By determining the components and their quantities in a representative sample of a particular kind of refuse that is to be incinerated, it is possible to calculate within reasonable limits the calorific value of all refuse of its type. The data can then be used as a basis of design for an incinerator in which to burn this particular refuse.

During normal dry weather in New York City, the moisture content of garbage is about 70 per cent, and the calorific value of both garbage and rubbish ranges from 7,500 to 8,000 B.T.U. per pound on a dry, inert-free basis. Experience with incinerators in New York shows that refuse with as much as 65 per cent garbage and 35 per cent rubbish may be burned without auxiliary fuels. This mixture may average about 45 per cent moisture and have a calorific value of about 4,500 B.T.U. per pound.

Table 9

PHYSICAL ANALYSES OF REFUSE BY WEIGHT AND VOLUME, CHICAGO, 1956-1958

Date	Number of Samples[1]	Per Cent by Weight						Per Cent by Volume						Density Lbs. per Ft.
		Paper	Grass	Garbage	Metal	Glass	Ashes	Paper	Grass	Garbage	Metal	Glass	Ashes	
3/56	10	50.1	*	6.4	18.5		25.0	68.4	. . .	3.9	18.1		9.6	15.00
4/56	8	64.0	. . .	7.4	13.9		14.7	80.5	. . .	4.4	10.7		4.4	14.38
5/56	9	57.3	11.9	5.6	14.0		11.2	79.0	4.6	2.6	10.9		2.9	15.20
6/56	6	60.7	6.5	2.5	13.6		16.7	. . .	. . .	. .	. . .		. . .	13.50
10/56	6	56.0	4.5	3.5	11.9		24.1	. . .	. . .	. .	. . .		. . .	12.40
2&3/57	4	49.2	. . .	6.1	17.5		27.2	69.3	. . .	2.7	17.9		10.1	14.80
4/57	1	53.3	19.7	3.2	9.3	5.9	8.6	69.4	12.4	1.7	11.5	2.5	2.5	16.33
9/57	2	42.0	23.0	3.6	7.4	5.4	18.6	58.9	20.8	1.7	9.1	3.0	6.5	. . . .
11/57	1	59.3	3.7	2.3	5.2	6.5	23.0	73.0	5.2	0.8	9.8	1.5	9.7	. . . .
2/58	1	57.6	. . .	5.7	11.6	9.3	15.8	82.0	. . .	1.8	10.3	2.5	3.4	7.60
2/58	1	56.3	. . .	1.5	7.5	6.0	28.7	81.7	. . .	0.8	8.5	1.8	7.2	8.11
2/58	1	70.4	. . .	2.6	8.0	6.9	12.1	86.7	. . .	1.1	7.7	2.3	2.2	8.38
4/58	3	63.7	. . .	1.5	8.1	5.8	20.9	82.3	. . .	1.0	9.0	2.4	5.3	9.11
6/58	1	54.7	34.4	0.8	6.2	3.5	0.4	71.8	22.9	0.8	2.3	2.1	0.1	12.22
Average		56.5	9.6	4.8	14.8		18.7	74.9	8.8	2.9	13.3		6.0	13.66

[1] One sample consists of one truck load of refuse (approximately three tons).

*Analysis for this category not performed; grass included with paper.

Table 10

MONTHLY DISTRIBUTION BY WEIGHT OF ORGANIC AND INORGANIC REFUSE DISPOSED OF IN NEW YORK CITY, 1939

	Per Cent Weight								
	Organic					*Inorganic*			
Month	*Garbage*	*Misc.*	*Paper*	*Wood*	*Total*	*Metal*	*Glass*	*Ashes*	*Total*
January	5.7	1.0	12.4	0.3	19.4	4.3	4.0	72.3	80.6
February	9.0	1.7	12.6	0.7	24.0	6.6	4.9	64.5	76.0
March	9.7	2.1	20.6	0.3	32.7	7.4	7.3	52.6	67.3
April[1]	18.1	2.8	21.6	2.0	44.5	7.4	6.9	41.2	55.5
May[1]	26.7	3.3	23.0	3.1	56.1	7.1	6.8	30.0	43.9
June[1]	35.1	3.8	24.3	4.6	67.8	6.4	6.8	19.0	32.2
July	43.8	4.1	25.5	5.9	79.3	6.6	6.3	7.8	20.7
August	23.1	7.4	37.6	3.8	71.9	11.6	5.1	11.4	28.1
September	12.6	5.6	26.7	4.9	49.8	8.2	9.1	32.9	50.2
October	10.1	3.8	31.0	2.6	47.5	8.9	4.0	39.6	52.5
November	6.6	1.9	18.0	2.1	28.6	3.8	2.9	64.7	71.4
December	3.5	0.8	9.0	0.8	14.1	3.1	1.9	80.9	85.9

[1] No data available; by interpolation.

Other investigations indicate that on a dry, inert-free basis, the B.T.U. content of most cellulose-type refuse is remarkably constant. For example, it was found that wood, brush, grass, paper, and garbage have calorific values ranging from 7,000 to 8,500 B.T.U. per pound when dry and free of inert material.

Analyses for Sanitary Landfill

It is not as important to know the physical and chemical composition of refuse to be disposed of by sanitary landfill as it is for disposal by incineration or composting. The flexibility of landfills in coping with the quantity and quality fluctuations of refuse has played a major part in their popularity.

The two factors of most importance, perhaps, in the quality of the refuse to be handled in sanitary landfills are (1) the amount of decomposable material and subsequently the rate of decomposition, and (2) the density of the material under compaction, both before and after decomposition.

Probably the most comprehensive survey of the characteristics of refuse disposed of in sanitary landfills was done in New York City in 1939. The contents of 168 trucks in which refuse had been collected from all types of areas were sorted and classified. Tables 10 and 11 show the results of the survey.

Analyses for Composting

Scientific composting requires a more accurate and detailed analysis of refuse, particularly chemical composition, than any other method of disposal. Modern composting is a method of refuse disposal in which an attempt is made to provide an ideal microenvironment of food, water, air, temperature, and shelter so that microorganisms can break down the refuse. Since food for the organisms is the refuse itself, and because the organisms thrive best within certain physical limits, it is essential that the composition of the refuse be determined so that adjustments can be made in these factors if necessary.

In connection with composting experiments at Michigan State University in 1954, garbage collected in East Lansing was studied to determine its physical composition and seasonal variations. Table 12 shows the results of the analyses of monthly samples of wrapped garbage that was separately collected during the year.

Some of the seasonal variations pointed out previously show up in Table 12, particularly in the citrus fruit and vegetable categories.

A physical analysis of refuse from residences in Chandler, Arizona, was made in 1953 by the United States Public Health Service in connection with composting studies. Table 13 is a list of the components and the per cent by weight of each.

Other investigations by the Public Health Service at the Communicable Disease Center Technical Development Laboratories in Savannah, Georgia, indicate that the moisture content of refuse for composting

Table 11

MONTHLY DISTRIBUTION BY VOLUME OF ORGANIC AND INORGANIC REFUSE DISPOSED OF IN NEW YORK CITY, 1939

	Per Cent Volume								
	Organic					*Inorganic*			
Month	*Garbage*	*Misc.*	*Paper*	*Wood*	*Total*	*Metal*	*Glass*	*Ashes*	*Total*
January	6.0	1.3	44.9	0.4	52.6	9.9	3.1	34.4	47.4
February	9.1	2.4	41.2	1.1	53.8	13.1	3.6	29.5	46.2
March	7.7	1.8	56.1	0.1	65.7	11.1	4.4	18.8	34.3
April[1]	9.0	2.9	54.7	1.7	68.3	10.8	4.1	16.8	31.7
May[1]	10.3	4.0	53.3	3.3	70.9	10.5	3.7	14.9	29.1
June[1]	11.6	5.1	51.9	4.9	73.5	10.2	3.4	12.9	26.5
July	12.9	6.1	50.5	6.5	76.0	9.9	3.1	11.0	24.0
August	14.3	6.9	49.1	8.3	78.6	9.5	2.7	9.2	21.4
September	8.0	9.3	44.0	8.4	69.7	12.8	4.8	12.7	30.3
October	6.9	4.7	52.5	5.7	69.8	13.2	2.1	14.9	30.2
November	6.0	2.5	45.1	5.9	59.4	7.6	1.9	31.0	40.6
December	4.7	1.1	37.4	1.4	44.6	8.4	1.8	45.2	55.4

[1] No data available; by interpolation.

Table 12

PHYSICAL COMPOSITION AND SEASONAL VARIATIONS OF GARBAGE, EAST LANSING, MICHIGAN, 1954
(Per cent by weight as received)

Constituent	*Jan.*	*Feb.*	*March*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Paper	17.2	16.7	21.1	18.1	15.4	23.4	17.5	15.4	25.0	26.7	24.2	21.1
Meat, fat, fish, and dairy products	5.5	4.4	9.4	7.7	10.3	10.1	8.2	4.1	5.4	16.7	13.8	8.6
Citrus fruits	14.8	19.9	17.5	23.5	10.1	9.4	0.8	2.9	3.0	4.7	8.1	21.8
Fruit, not citrus	8.9	12.5	5.3	1.7	9.8	5.6	2.3	8.0	7.2	5.7	6.5	5.3
Greens and other salad vegetables and melons	12.7	14.2	7.1	13.8	11.9	29.8	46.3	25.2	39.2	18.0	7.8	13.8
Coffee grounds and tea leaves	0.8	3.9	11.0	2.9	3.2	2.6	2.9	4.2	1.8	2.8	3.1	7.3
Bread, pastry, sugar, and cereals	13.6	7.8	4.9	12.4	15.2	6.1	7.7	5.8	5.0	8.3	12.4	0.0
Corn, baked beans, potatoes, and other root vegetables	19.4	12.8	14.1	10.4	14.3	5.0	5.5	12.1	6.7	10.6	11.0	12.8
Miscellaneous	7.1	7.8	9.6	9.5	9.8	8.0	8.8	22.4	6.7	6.5	13.1	9.3

Table 13

ANALYSIS OF REFUSE FROM RESIDENCES IN CHANDLER, ARIZONA, 1953

Components	*Per Cent*
Tin cans	8.7
Rags	1.9
Other metals	1.1
Total materials with potential direct salvage value	11.7
Garbage	21.8
Paper and paper products	42.7
Leaves, grass, tree trimmings	1.3
Fines in a pulverized mixture	7.3
Total materials with potential indirect salvage value (compostable fraction)	73.1
Glass	7.5
Wood	2.3
Rubber	0.7
Plastics	0.4
Leather	0.3
Stones and ceramics	0.3
Fines in a pulverized mixture	3.7
Total materials that require further handling	15.2

should be modified to obtain the "liquid content" (see Chapter 9, Composting).

Chemical Analyses

Most investigations of the chemical composition of refuse have been made in connection with composting. But it is difficult to compare one set of analytical results with another. Even though the same techniques are used for the chemical analyses (which may not be the case), the methods of obtaining the samples for analysis may be completely different. Furthermore, the same terminology and definitions may not have been used. "Garbage" in one locality may mean only food waste, while in another it may mean food waste, paper, cans, and bottles.

Until standard methods of sampling and analyzing refuse are developed and widely used, it will be impossible to determine whether the wide differences in analytical results are due to differences in refuse composition or to different techniques and definitions.

Compaction Characteristics

The compaction characteristics of refuse have received increased attention in recent years because of the changes in refuse composition, which tend to reduce the density of the refuse.

Collection vehicles have been designed to compact the refuse, resulting in increased density and consequently a larger load. These vehicles may reduce the material to one-half or one-third of its original loose volume.

Compaction is one of the most important phases of an efficient, sanitary landfill operation. If the refuse is properly compacted before covering, less land is used and there is less settling of the area after it is filled.

The degree of compaction in a landfill is usually reported as the ratio

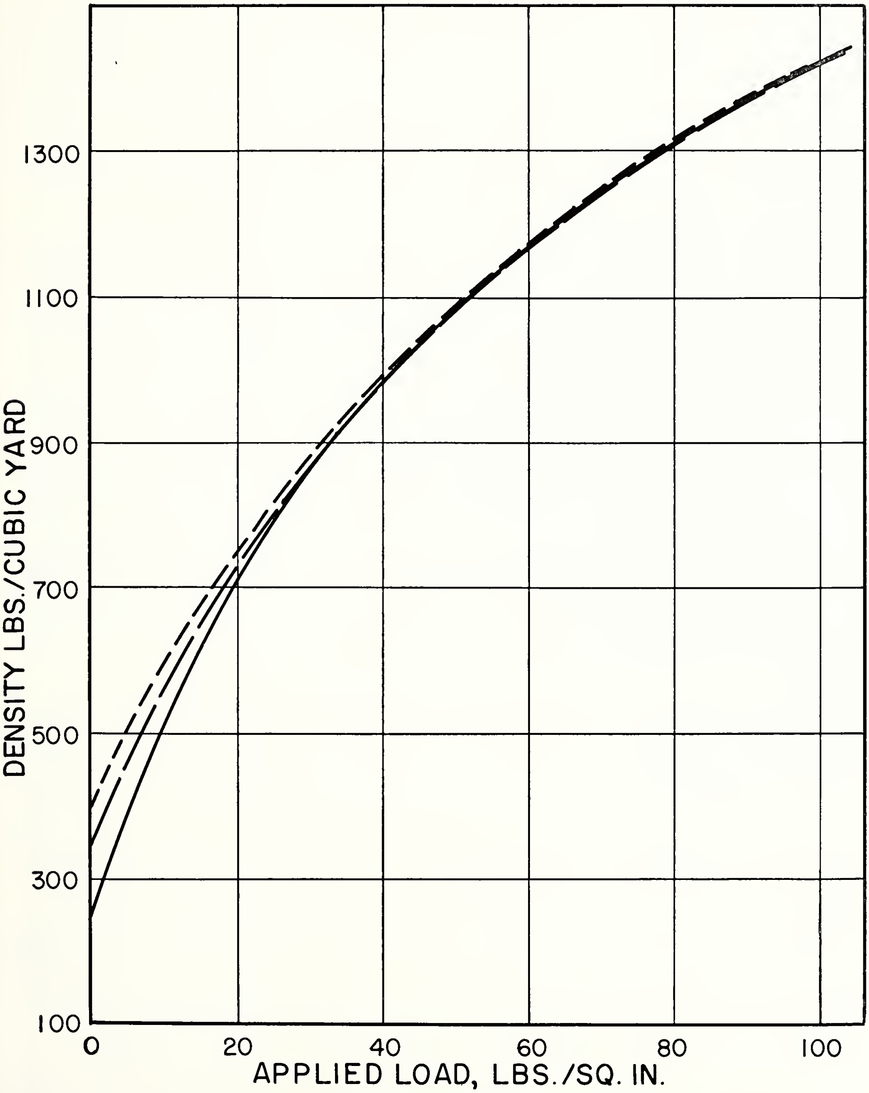


Fig. 19. Results of compression tests on household refuse from garbage cans in Chandler, Arizona, showing the increased densities produced by various compaction pressures, 1954.

of the volume of refuse received to the volume after compaction. The ratios reported show that landfills vary widely—from as low as 1 to 1 to as high as 3 to 1.

The differences in reported compaction ratios are partly accounted for by the differences in densities of the refuse when it is delivered to the landfill. Obviously, refuse delivered in a loose condition in an open truck can be reduced in volume by compaction more than refuse from a packer truck that may carry refuse of twice the density of the other.

Another factor that may account for different compaction ratios in landfills is the method of determining the incoming volume of refuse. In some cases the volume is recorded as the truck capacity regardless of whether the truck is only partly full or is filled to more than what is considered its capacity.

Indifferent methods of determining the volume used in the landfill may also lead to incorrect calculations of compaction ratios.

The most reliable method of determining compaction of refuse in a collection vehicle, landfill, or in any other situation is to calculate the density of the material under consideration. This calculation is based on weight and volume and, as it was pointed out earlier, weighing refuse is the only accurate method of determining quantities.

If the densities of compacted material in sanitary landfills in this country were accurately determined, they would probably not vary as widely as the compaction ratios indicate.

A test of the compressibility of refuse was made by the United States Public Health Service at Chandler, Arizona, in 1954. In the test, household refuse was subjected to increased compressive loads. Figure 19 shows the results of these tests. They indicate that at pressures of 100 pounds per square inch the density of domestic garbage-can refuse is more than 1,400 pounds per cubic yard, which approaches the density of water (1,685 pounds per cubic yard).

3 SELECTING DISPOSAL METHODS

The selection of the best methods of refuse disposal for a city is of utmost importance. It involves many factors; careful consideration must be given to all and a number of questions answered before a decision can be made:

1. What methods are technically feasible; what are the limitations of each?
2. Do local conditions make some methods particularly suitable or unsuitable?
3. What factors, such as good public health features or fewer potential nuisances, favor one method over another?
4. Will weather, mechanical failure, or other circumstances interrupt disposal procedures and with what results for the city?
5. What are the costs of the various methods; how do they vary and with what factors?
6. What effect do collection procedures have on costs of disposal?
7. What methods can be adapted economically to changing conditions in the city?
8. Will salvage or reclamation pay part of disposal costs?
9. What elements in each method are likely to gain public support or meet with antagonism?

Characteristics of Methods

Since each disposal method is discussed in detail in the following chapters, only the essential operations of each are given here as background for the factors that must be considered in deciding on methods.

Sanitary Landfills

Sanitary landfill operations are usually performed by depositing refuse in a natural or man-made depression or trench, or dumping it at ground level, compacting it to the smallest practical volume, and covering it with compacted earth or other material in a systematic and sanitary manner. Before operations begin, a site must be selected and surveyed; the site prepared; access roads, control grades, and drainage provided for; and equipment selected. Other steps may be required, depending on climate and the site. In some cases special provisions must be made for controlling blowing papers, odors, dust, and fire; and special equipment and personnel facilities may be needed.

Well planned and operated landfills have several advantages: they

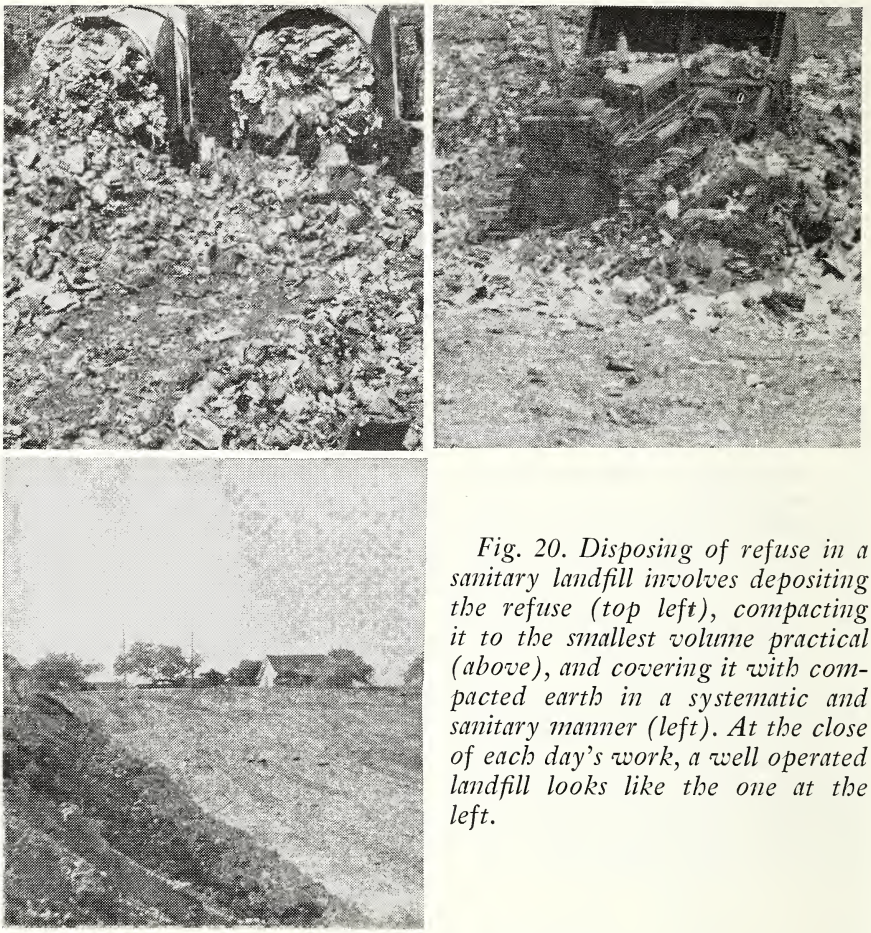


Fig. 20. Disposing of refuse in a sanitary landfill involves depositing the refuse (top left), compacting it to the smallest volume practical (above), and covering it with compacted earth in a systematic and sanitary manner (left). At the close of each day's work, a well operated landfill looks like the one at the left.

are economical; they require a relatively small capital investment; they may reclaim land that is otherwise useless; and they cause almost no air pollution. They do have disadvantages, however: they frequently require longer and more costly hauls than some other methods; they require more land than some other methods; and operational problems may be frequent in inclement weather.

Central Incineration

A central incineration plant—either municipally or privately owned—is one in which combustible refuse is reduced to ash by high-temperature burning. Refuse from collection trucks is dumped on a charging floor or in a storage area or pit, the refuse is charged into furnaces, temperatures and drafts are carefully controlled to insure as complete combustion as possible, and ashes and noncombustible residues are disposed of in landfills or salvaged.

Incineration is advantageous because a relatively small site is required for the plant, the length and cost of the haul to the plant is usually less than for landfills and other methods; and the residue from the burning is usable fill material. On the other hand, the capital costs of an incineration plant are relatively high; operating costs, considered alone, are also usually relatively high; and it is not a complete disposal method—ashes and other residue from the furnaces must be hauled to a disposal site.

On-Site Incineration

On-site incinerators are those used in and outside of houses, in apartment buildings, stores, small industries, hospitals, and other institutions to burn refuse produced on the premises. They are of many types and sizes for various uses. The advantages are that the amount of combustible refuse that must be collected and disposed of is reduced by the amount that is burned in such incinerators. Householders and others who use them often find them an advantage because refuse does not have to be stored on the premises; it can be disposed of almost as soon as it is produced, reducing nuisances and hazards from it. On-site incinerators do sometimes cause unpleasant odors, smoke, and fly ash, however.

Grinding Food Wastes

Garbage can be disposed of by grinding it and flushing it into sewers. There are home grinders; grinders used in restaurants, produce terminals, and supermarkets; and grinders for centrally located stations operated

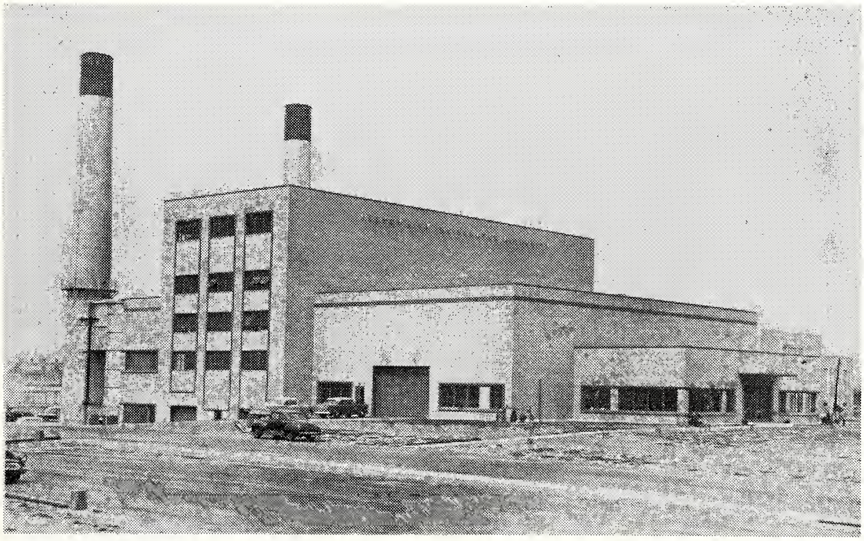


Fig. 21. An incineration plant includes equipment necessary to burn combustible refuse without nuisance, reducing it to ash. The scale house and administrative offices for this plant in Jersey City, New Jersey, are shown at the right.

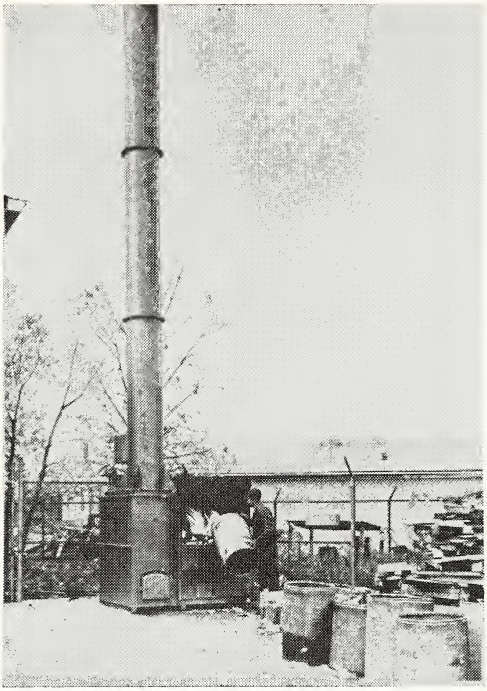


Fig. 22. On-site incinerators include those used in homes, institutions, industries, and businesses. This portable industrial incinerator will burn 280 pounds of dry wastes an hour. The stack is self-supporting; needs no guying.

by a municipality. The principle of operation is the same for all. Garbage is kept or collected separately from other refuse, it is ground or shredded in the grinder as water is added, and it is flushed into the sewers. Household grinders are considered the ultimate in convenience and sanitation because they almost eliminate garbage storage. Widespread use of household and commercial grinders reduces the amount of garbage that must be collected and disposed of; central grinder stations are especially advantageous to cities in which there is a great deal of wet garbage, which does not burn well and may not be suitable for feeding to hogs. Grinder stations are relatively simple to build and operate. However, grinding requires that other refuse, which is probably 85 to 90 per cent of the total volume, be collected separately.

Feeding Food Wastes to Swine

Garbage can be disposed of by feeding it to swine. It is collected separately, the unedible refuse is separated from it, it is cooked to destroy disease organisms, and it is fed to hogs on farms, usually especially built for garbage feeding. Municipalities no longer operate such hog farms, but in some cases they contract with hog raisers to use the garbage for feed. In most places, garbage is collected by private haulers who make their own arrangements with restaurant owners and operators of institutions.

Because all states require that garbage be cooked before it is fed to hogs and because most farms are now far from cities, garbage feeding is not usually as attractive economically as it once was. Health and agriculture department regulations are necessary to prevent or control animal diseases and nuisances created by the disposal process. Furthermore, only edible food wastes are disposed of; other refuse must be collected and disposed of by other methods.

Composting

Composting is sometimes defined as a rapid but partial decomposition of moist, solid, organic matter—primarily garbage—by the use of aerobic microorganisms under controlled conditions. The result is a sanitary, nuisance-free, humus-like material that can be used as a soil conditioner and fertilizer. By 1960 no city had set up a full-scale composting plant; experience was limited to experimental plants. Theoretically, the advantages are several: the end product is valuable and should result in revenue for a city; the site for the plant can be small; and hauling distances and costs are not great. On the other hand, capital costs may be high; in 1960, at least, there was an uncertain market for the end product; and storage of the end product may be a problem.

Salvage and Reclamation

The term salvage and reclamation covers a number of "disposal" processes: sorting of refuse either manually or mechanically, for metals, tin cans, glass, paper, rags, and other materials that can be resold; rendering of animal wastes for fats; dehydration of garbage to be used for hog feed; composting; and landfills that reclaim otherwise unusable land.

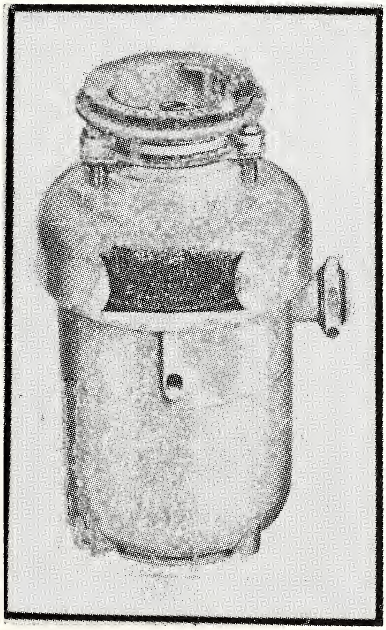


Fig. 23. More than two million household garbage grinders were installed during the 1950's. Many cities encourage the installation of them and some require installation in new dwellings.

Garbage reduction, in which grease is extracted from cooked garbage and sold, was once a widely used form of salvage but it has not been a major disposal method for 40 years or more. In fact no city today uses salvage as a principal means of disposal; it is usually a "partial" method or side-line of some other method. Decreasing prices for salvage materials and increasing labor costs frequently make it uneconomical.

Dumping

Open dumps are still common in some places, but since they are the source of a number of public health and safety problems—disease, air and water pollution, fires, mosquitoes, rodents, insects—they are not recommended. It usually requires little more cash outlay to turn them into sanitary landfills.

Legal Restrictions

State and local ordinances may prohibit some kinds of disposal or control various aspects of them. Air pollution, health, sanitation, fire, nuisances, zoning, and other laws affect the ways in which various disposal methods can be operated and the costs of them. All should be investigated before a decision is made on what methods to use. In addition, the agency responsible for disposal may want to get additional regulations and ordinances passed that will help control disposal activities.

Regardless of what they control, the ordinances must be legal. If discriminatory, they may be declared unconstitutional. Typical ordinance provisions for disposing of refuse are given in Appendix B.

Ordinances in many cities make dumping illegal, for instance, but it is a problem nevertheless. Not only does the producer of large volumes of refuse dump illegally but also the householder who does not want to put beer cans, liquor bottles, or some particularly unpleasant smelling object in his refuse container. Instead, he dumps them in empty lots or along a roadside.

It is not easy to enforce regulations against illegal dumping because the violator is rarely caught in the act. Furthermore, it may be cheaper and easier for the city to correct the violation than to find the guilty person. Residents of a neighborhood in which illegal dumping takes place are rarely able to tell when the violation occurred or give the names or vehicle license numbers of the violators. However, public concern with dumping violations has increased in recent years and more violators are being apprehended.

The most satisfactory method of punishment is not a fine or imprisonment but widespread newspaper publicity and the requirement that the violator clean up the illegally dumped refuse.

The best preventive measures are good refuse collection services and well kept city streets and vacant lots. Educational programs appealing to civic pride, in which the newspapers and other mass media take part, are also helpful.

Dumping at sea was fairly common in sea coast cities until 1933, when the United States Supreme Court prohibited it in a decision involving New York City.

PUBLIC HEALTH ASPECTS

The most restrictive limitations put on refuse disposal methods are those imposed in the interests of public health, although local regulatory agencies charged with protecting aquatic life and recreational facilities may also limit the methods that can be used. Disapproval of either method or site by citizens groups, growing out of real or fancied considerations of sanitation, may be important in making a decision. But seldom do such groups make valid objections that have not already been considered by public health and sanitation officials.

The term "public health" is interpreted broadly in regard to refuse disposal. It means not only direct transmission of disease to men and animals and the reservoirs from which disease may emerge, but also such environment depreciating factors as odor, visible smoke, gases, dust, noise, fly ash, drifting paper, heavy traffic, and unsightly appearance. The latter are commonly known as nuisances but they are considered here as sanitation factors of importance to the public health and welfare.

The most serious public health considerations have to do with rodent and insect vectors, which may be present along with myriad nuisance factors in a single ill-designed refuse disposal operation.

It is important to understand, however, that no disposal method is free of all health hazards and nuisances unless it is most carefully planned and efficiently operated.

Sanitary Landfills

The chances of satisfactorily operating a sanitary landfill weigh heavily in the decision of officials to adopt the method. Furthermore, public acceptance of landfills often comes only after demonstration that they can indeed be sanitary. Fresno, California, officials, for example, at first met a great deal of resistance to a landfill located some distance from the city. But after it had been well operated for several years they met no opposition to the purchase of land for a fill much closer in.

There are health and nuisance problems with some landfills, however. Inadequate depth or insufficient compaction of cover material in landfills may permit flies to emerge from eggs or larvae in the raw refuse at the time it is collected. Even with efficient operation of a landfill, some fly control measures are usually necessary around the disposal site, particularly large ones.

Carelessness in operating a sanitary landfill sometimes results in smouldering interior fires that cause odor and smoke if the landfill earth cover becomes ineffective because of uneven settlement or surface cracks.

Dust stirred up by trucks and other equipment on a landfill or going over unpaved approach roads in dry weather is sometimes a nuisance to

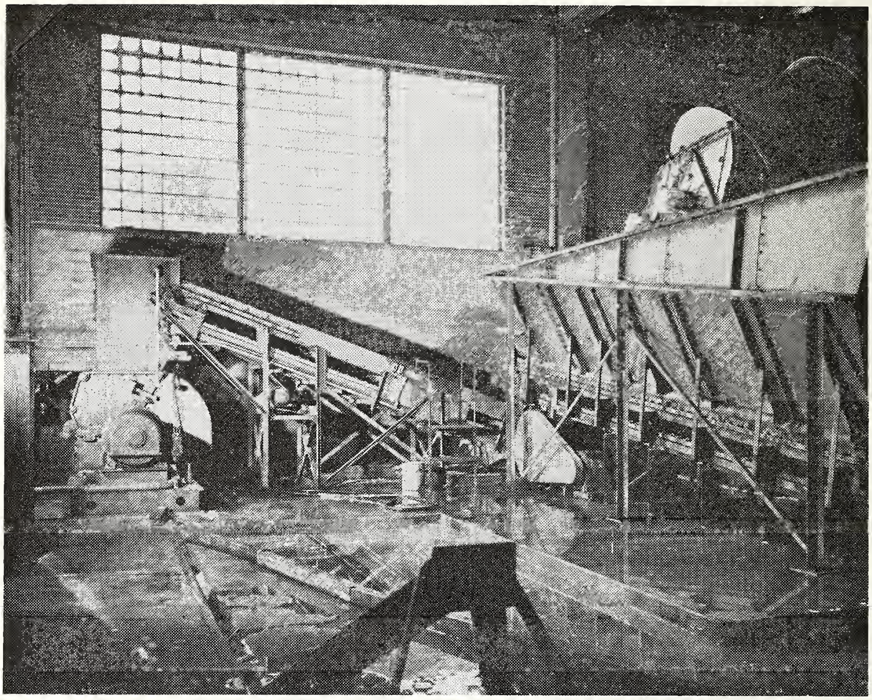


Fig. 24. Central grinding stations at which garbage is ground and disposed of through the sewerage system are used in some cities. Large grinders are especially convenient for disposing of condemned foods. This garbage grinding plant is at the refuse transfer station in Washington, D. C. The storage bin and feeders are at the right.

neighboring areas. While such nuisances are seldom the deciding factor in selection of landfills as the method of disposal or in selection of sites, they nevertheless are public health and welfare aspects to be taken into account.

The possibility of contaminating surface and ground waters through the use of sanitary landfills has recently became a matter of concern to public health and water pollution control authorities. Experience with well planned and operated landfills, however, gives little if any evidence that ground waters are being harmfully polluted by this method of disposal.

Central Incineration

From the standpoints of health and sanitation, disposal by central incineration is probably the most desirable method. In some cities it is difficult to give much consideration to any other. If an incinerator is centrally located, a high degree of operating and "housekeeping" efficiency is required.

Real or fancied nuisances from truck noises and traffic dangers to children in the streets are more common objections to incineration plants than are the health hazards of smog, smoke, and other air pollutants or an unsightly environment. The deciding factor in using incinerators as the method of disposal is more often whether residents approve a site than whether the health authorities do. It is almost axiomatic that residents of any area think the only location for an incineration plant is "somewhere else." Incinerators have been operated near high-value residential areas without complaint, however.

Grinding Food Wastes

In new districts of growing cities the use of home garbage grinders has become so widespread that even some very large cities now estimate that 25 to 30 per cent of all garbage is ground and flushed into sewers. The public health aspects of the practice—other than the positive one that garbage storage on the premises is eliminated—are largely those associated with sewage treatment problems. Wherever the method is used, however, its effect on the sewage disposal system must be taken into account. A number of cities prohibit installation of grinders because sewers and other sewage disposal facilities are inadequate.

An enclosed central grinding station must be well operated by a municipality to prevent the problems and nuisances common to any central disposal plant from developing.

Feeding Food Wastes to Swine

Feeding of garbage to swine is a disposal method in which both disease potential and aesthetics are part of the public health considerations. Health authorities have long been concerned with the reservoir of trichinosis maintained by the practice of feeding raw garbage to swine, even when the strictest precautions are taken to minimize rat and fly infestation of the feeding area. Hog feeders are equally anxious that cholera not wipe out their herds, leaving them without a salable commodity and with contracts that require them to dispose of tons of garbage each day.

While public health officials have been mainly concerned with trichinosis in man, it took an epidemic of animal disease to all but end the practice of feeding raw garbage to swine. The explosive emergence of vesicular exanthema from a California reservoir in 1952 led to the adoption of legislation or regulations banning the feeding of raw garbage to swine in all 50 states.

Opposition has grown to feeding garbage to swine in areas that are within economical haul distances of a city. Hog farms are considered a nuisance. Zoning ordinance provisions for them, therefore, are becoming more and more restrictive, with the result that with the need for approval of both health and other public authorities to set up a hog farm, hog feeding as a method of garbage disposal has been eliminated in many areas. With the method eliminated some cities have been forced to combine garbage collection with that of other refuse that previously

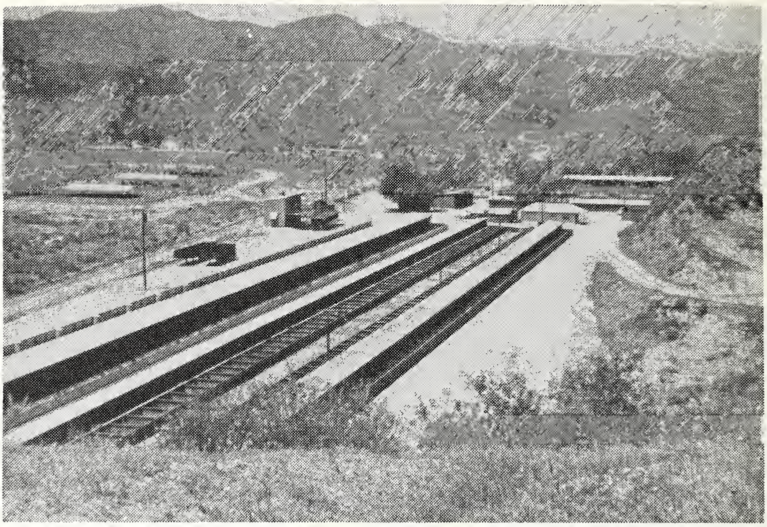


Fig. 25. Garbage is sometimes disposed of by cooking it and feeding it to hogs. This is a hog ranch in Los Angeles County on which garbage is used for feed.

had been disposed of without undue health hazards or nuisance, requiring substantial and often costly new techniques.

Composting

Composting has been demonstrated as a sanitary method of refuse treatment. Fly larvae and pathogenic organisms are destroyed if the refuse composted is turned periodically so that all portions of it come into the high-temperature zone at some time. Because there is no appreciable amount of experience in the United States with this process, health authorities are not certain what sanitary control measures are necessary for composting plants. Good housekeeping practices similar to those used at central incineration and garbage grinding plants are necessary, however.

Dumping

As recently as 1953 some communities in the environs of great metropolitan centers were disposing of their refuse by (1) dumping it on a spreading area during the morning; (2) permitting hogs to ferret out garbage during the afternoon, while rags, paper, bottles, large metal pieces, and other objects were salvaged; (3) burning the combustible remains in the evening to reduce the volume and facilitate further salvage of metals; and (4) pushing the residue over the escarpment of a fill before arrival of the first refuse trucks the next morning. Smoke, odors, and other air pollutants accompanied the burning. Flies abounded in the vicinity, although probably to a lesser degree than if the refuse had not been burned daily. Likewise, rats were somewhat fewer than in open dumps, although a sizeable number greeted the arriving trucks each day. Furthermore, trichinosis and vesicular exanthema were perpetuated in hogs (see Chapter 8, Feeding Food Wastes to Swine). And in southern climates, where Aedes Egypti mosquitoes are found, cans and discarded tires partially filled with water were breeding places for the mosquitoes. In many cities such operations still take place along a main highway and only a short distance from residences.

Rats, if permitted to do so, will infest a dump as long as there is garbage for food. Any improvement in the disposal method will reduce the food supply for them and they will migrate in search of other food. Consequently, the mere abandonment of the town dump in favor of a more enlightened method of refuse disposal may increase public health hazards unless the rats are destroyed. In fact, there is almost no method of refuse disposal in which good housekeeping practices do not require attention to rodent control measures.

Characteristics of the City

The disposal methods used in a city depend to some degree on the "kind" of city it is—because the kind of city affects the amounts and kinds of refuse produced in it. Geographic location, climate, standards of living, density of population, and the main sources of income of the residents are all important.

Geography and Climate

In mild and semi-tropical climates few if any solid fuels are used for heating, with the result that there are few ashes to dispose of. In warm climates there are also large quantities of garden and yard wastes throughout most of the year.

In parts of the country that are cold in the winter there are ashes part of the year and there are widespread fluctuations in the amounts of refuse produced. Furthermore, frozen ground makes landfills more difficult to operate in the winter months.

Areas in which rain is frequent and heavy may require different techniques for disposal than dry areas. Refuse may have to be predried if it is to be incinerated, for instance.

Frequent smog may eliminate central incineration as a disposal method, or require that special precautions be taken to decrease smoke emissions.

Cities in parts of the country in which earthquakes, floods, hurricanes, and other weather disasters are not infrequent must use disposal methods that are reliable even under such unfavorable conditions.

Population

The number of people living in a city and whether most live in large apartment buildings or in single-family or two-family dwellings influence the selection of disposal methods. In cities in which many people live in large apartment houses, for instance, a good deal of refuse is disposed of in apartment-type, on-site incinerators.

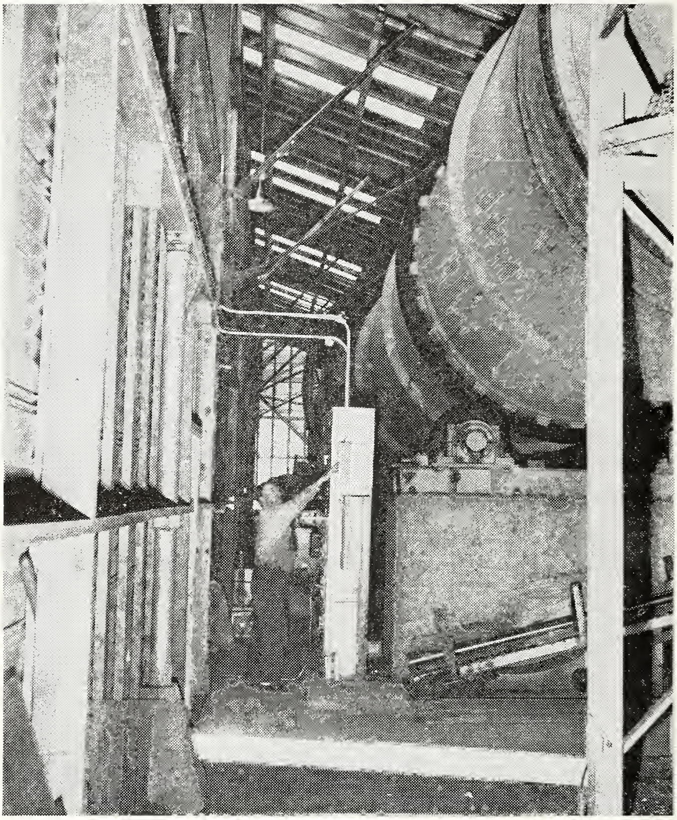


Fig. 26. This Dano digester composting plant in Sacramento, California, can handle 50 tons of refuse a day.

In areas in which there are many new houses, a good deal of garbage is disposed of in home grinders.

Standards of living also influence the quantities and kinds of refuse—and in turn the disposal method. The higher the income and the standard of living the more waste there is. Furthermore, in high-income areas, the residents frequently require high-standard refuse collection and disposal services and are willing and able to pay for them.

Sources of Income

Cities in which industry and big business are the main sources of income differ from resort cities, for example, in the amounts and kinds of refuse produced.

Large industrial cities often have to dispose of industrial wastes by special methods. Some industries produce highly mineralized liquid wastes that if deposited in landfills permeate to and pollute underground waters. Others produce explosive or noxious refuse that cannot be burned in incinerators. Still other industries produce large quantities of salvageable refuse and they may be close enough to markets for salvage to make it worth while to sell at least some of it.

Tourist and resort centers, on the other hand, often have disproportionate amounts of food wastes from restaurants to dispose of. Large business centers frequently have larger than usual quantities of paper refuse.

Capital and Operating Costs

The costs of setting up and operating a refuse disposal facility of any kind are specific but they vary considerably with the methods.

Computing Costs

The financial ability of a municipality to meet both capital and operating costs of any kind of refuse disposal facility is most important. It is certainly unwise to recommend a method beyond the financial capabilities of the city. Besides the obvious costs for the site, construction, and operation, there are other costs, as well as revenues, that are not always considered but should be. Among them:

1. If a bond issue is used to finance capital outlay, the costs of retirement and interest on the bonds must be included as part of the costs of the disposal facility.
2. Since interest paid on bonds is part of costs, it seems logical to some also to include as part of the costs the interest lost to the city on money taken from general revenues to purchase large pieces of equipment. This is a debatable point, however, and frequently the so-called "lost" interest is not included in costs, since a municipality is not a profit-making organization that must show a return on its investments.
3. Some also argue that the amount of taxes lost to the city on property used for a disposal facility should be included as part of costs.
4. It is important to determine the reasonable life expectancy of equipment and include the costs of depreciation and repairs as part of facility costs.
5. In computing operating costs, consideration should be given to increases in salaries and administrative costs in the future and to possible increases in costs of materials.
6. Careful consideration should be given to the costs of the land for a landfill, what its useful life will be as a disposal site, and whether its value can be expected to increase or decrease by the time it is no longer needed as a disposal site. Changing property values are important. In Detroit, for example, large tracts of land of relatively little original value were developed through landfill operations and site improvements, increasing their value several times.
7. Population growth should be projected and the increased amount of refuse to be disposed of must be calculated and accounted for in costs.

8. By-products of the disposal process and salvage may have sale value —fats and compost, for instance. Revenues from salvage materials and by-products must be included in determining long-term costs, but at the same time the possibility that the market value of by-products and salvage will change must also be considered. (It is almost impossible to predict long-range markets for salvage and by-products with much accuracy.) (Chapter 10 deals with salvage and reclamation operations.)
10. Sufficient money must be allocated for operating and maintenance so that the plant and equipment are kept in good condition and as attractive in appearance as possible. Experience shows that good maintenance pays big dividends.

See Chapter 11, Management of Disposal Facilities, for additional information on costs.

Comparative Costs

It is difficult to compare disposal costs from various cities. In fact, it is sometimes difficult to compare costs from year to year in the same city. Comparisons are difficult primarily because of (1) differences in

Fig. 27. Some refuse can be salvaged and reclaimed, and so in most cities there are salvage yards operated by private business, which reduce the amount of refuse the city must dispose of. Salvageable heavy metals are almost always in demand.

accounting methods, including computation of overhead and equipment amortization; (2) variations in labor rates and employee benefits; (3) differences in conditions (for example, it is necessary to buy and import earth cover for sanitary landfills in areas in which suitable cover is not available); (4) differences in disposal techniques; (5) exclusion from computations of collection costs that are attributable directly to the disposal method used; (6) inability to express the exact work done in a convenient unit of measurement (for example, extraordinary and costly air cleaning equipment needed for an incineration plant in a city where air pollution is a critical problem).

A comparison of costs for the three near-complete disposal methods—sanitary landfills, incineration, and composting—gives a broad indication of the relative economics of them. Partial disposal methods such as feeding garbage to hogs, garbage grinding, and domestic incineration, however, cannot be compared in the same way that the near-complete methods can. Costs of each method are discussed in the chapters on methods.

Initial capital costs for sanitary landfills, including costs of site acquisition and preparation, are roughly one-fourth to one-half of those for central incineration. The modern, fully mechanized composting plant costs about what an incineration plant does.

Operating costs for sanitary landfills are approximately one-third to one-half of those for incineration unless hauling costs for landfills are excessive.

Meeting the Costs

Each year more cities—particularly small ones—discontinue the practice of meeting refuse collection and disposal costs solely from general taxes and instead charge directly for them. There are several advantages to financing disposal facilities as a public utility as opposed to financing by taxes on the basis of assessed valuation of each property:

1. A capital fund can be set up, which permits accumulation of money for large expenditures.
2. Reserves can be established, such as a replacement fund for worn-out or obsolete equipment.
3. Long-range planning can be done effectively with the assurance that funds will be available when needed.
4. Revenue bonds to finance large capital expenditures can be issued and sold.

COORDINATION OF COLLECTION AND DISPOSAL METHODS

Disposal methods are influenced by collection methods and vice versa. They must be coordinated. The costs of separate collections of various components of refuse, which is necessary for some disposal methods, and the costs of hauling refuse to disposal facilities are important factors in deciding on disposal methods. In addition, the inconveniences and nuisances created by various methods of collection and hauling must be considered. (Refuse collection problems are discussed in detail in *Refuse Collection Practice.*)

Separate Collections

Separate collections are usually objectionable, particularly to householders, so the methods that require the fewest kinds of collections are usually favored because of both convenience and costs. However, separate collections are sometimes necessary for operating, health, and salvage purposes. In fact, some disposal methods are practical only if some components of refuse are completely or almost completely separated from other kinds. Disposing of garbage by feeding it to hogs, for instance, requires that garbage be collected separately from other refuse (see Chapter 8).

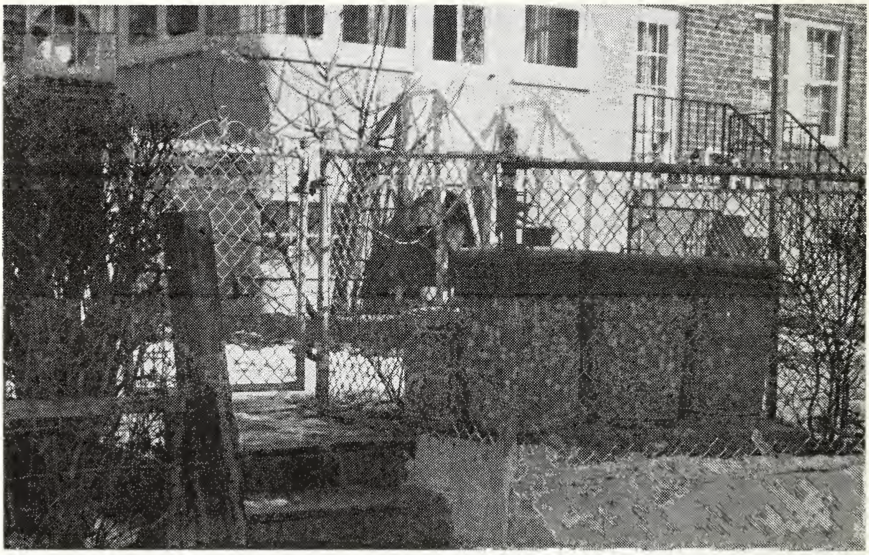


Fig. 28. Some disposal methods require that different kinds of refuse be collected separately, and it is important, therefore, that collection and disposal methods be coordinated. If there are separate collections there must be separate storage containers. In Washington, D. C., garbage, rubbish, and ashes are collected separately, requiring the householder to have many containers. The small container at the left is for garbage.

Refuse can be separated (1) at the source—by the householder, business, institution, industry, or collection crew; or (2) at the disposal facility—by collection or disposal crews or by scavengers.

Separate storage of various kinds of refuse at the source has obvious advantages. In fact, separation of refuse components after they have once been stored together sometimes is not practical or possible. More important, however, is that the cost of storing refuse components separately at the source is negligible in comparison with the costs of separating it by collection or disposal crews. Of course, costs of separate storage at the source are borne by the producer of the refuse—not by the city—and are not taken into account in computing collection costs. Nevertheless, separate collections increase collection costs over those for combined collections if the frequency of collections is the same. In some circumstances there may be some cost advantages, however, because separated, nonputrescible refuse can be collected less frequently than combined refuse. Table 14 gives common practices for separation of refuse for various disposal methods.

If refuse separations by the householder or business are to be successful and practical, the regulations for preparation and sorting of the refuse must be reasonable. Experience shows that householders will separate refuse into two or even three kinds and store them separately—but

Table 14

COMMON PRACTICES FOR SEPARATION OF REFUSE FOR VARIOUS DISPOSAL METHODS

Disposal Method	*Refuse Suitable for Method*	*Refuse Unsuitable for Method*[1]	*Where Separated*
Sanitary landfills	Mixed	Tree trunks, stumps; hazardous refuse; offal	Disposal site
Central incineration	Mixed	Large objects that clog hoppers; large metal pieces; heavy wire; hazardous materials; heavy timbers; tree trunks	Combustibles at source; sometimes all refuse collected together
Central grinding	Garbage; some paper	Inert material that cannot be reduced at sewage treatment plant or cannot be carried in sewers; cans, metals, glass, earth	Source; wrapping usually prohibited
Feeding food wastes to swine	Garbage	Paper; citrus rinds; cans; glass	Source; wrapping prohibited
Composting	Organic desirable; inorganic acceptable	Large ungrindable objects—tires, metals, logs	Source or plant
Salvage and reclamation	Materials with resale value	Varies with market for salvage	Source or disposal facility
Open dumping[2]	Some non-putrescibles	Putrescibles	Source or dump
Open burning[2]	Tree branches, trunks; combustible rubbish	Garbage; other putrescibles	Source

[1] Complete or almost complete separation desirable in all methods.

[2] Not a recommended disposal method; acceptable only under special circumstances.

usually only after they are "educated" to the necessity for it. It may take five years to get the public to comply with a new system of refuse separation even under a good administrator; it may never be achieved under mediocre or poor administrative practices.

Merchants are usually less willing than householders to comply with refuse separation regulations for combustible and noncombustible rubbish, primarily because it is difficult to train employees to make the correct separations. Many large businesses prefer to employ private collectors at their own expense to avoid difficult and bothersome regulations.

Regardless of how reasonable the regulations are and how intense an educational campaign is to get people to separate refuse, full compliance is never achieved, so that it is necessary to further separate refuse at the disposal point. Usually the more complete the separation is the more efficient the disposal operation is.

Separation of refuse at the disposal facility almost always immediately precedes actual disposal, whether the separation is done mechanically or manually or whether separation is complete or incomplete. Refuse to be separated is usually dumped on a sorting floor of an incineration plant or in an open space adjacent to a landfill. Obviously if the refuse is dumped into storage bins or hoppers when it reaches an incineration plant or into the fill when it reaches the site, there is no opportunity for sorting.

The degree to which refuse components are separated depends largely upon costs. There is usually some latitude in the amount of separation necessary for any method, and costs may be the deciding factor. Complete separation is usually more costly than partial separation, but the savings from partial separation may be cancelled out by increased costs in disposal operations because the refuse is not completely separated.

The costs of space, equipment, and personnel to separate refuse at the disposal facility must be computed; and the possibilities of vermin infestation of sorting areas, injury to employees, damage to equipment, the appearance of the site, and interference with disposal must be considered in making a decision to use a disposal method that requires separation of refuse at the disposal site.

Hauling

Hauling costs depend on the length of hauls, the type of route the trucks must take, the amount of traffic encountered along the routes, and the kinds and amounts of equipment and the number of employees needed.

The longer the haul and the more traffic encountered, the higher the operating costs. Long hauls also frequently require larger route trucks or transfer trucks, as well as transfer stations, if refuse is taken from route trucks and loaded on transfer trucks, barges, or railroad cars. The number of employees varies with the number of trucks used and the amount of supervision required.

In computing total hauling costs, all expenses from the time refuse is loaded until it is unloaded at the disposal facility must be included: personnel costs and operating expenses. (Personnel costs include not only salaries, but also vacation and sick leave pay, health insurance, retirement funds, and other fringe benefits.) In addition, capital costs, depreciation, and maintenance of equipment (or rents, if the equipment is not owned by the city) must be included. If some equipment used to haul refuse

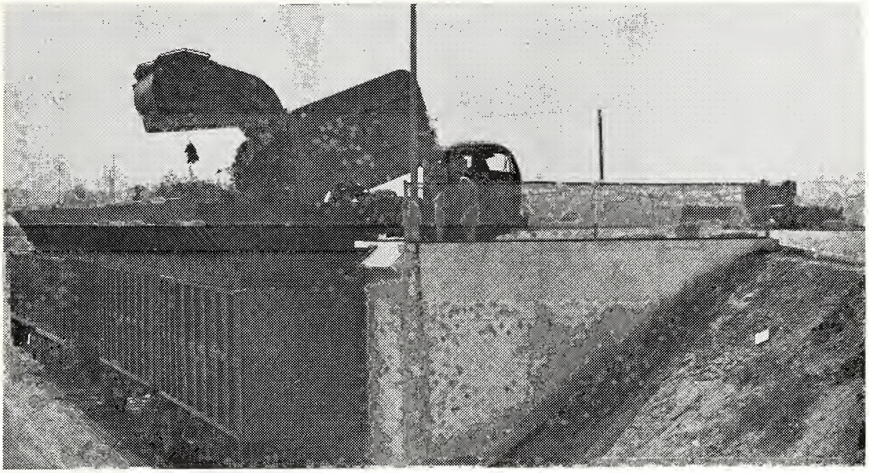
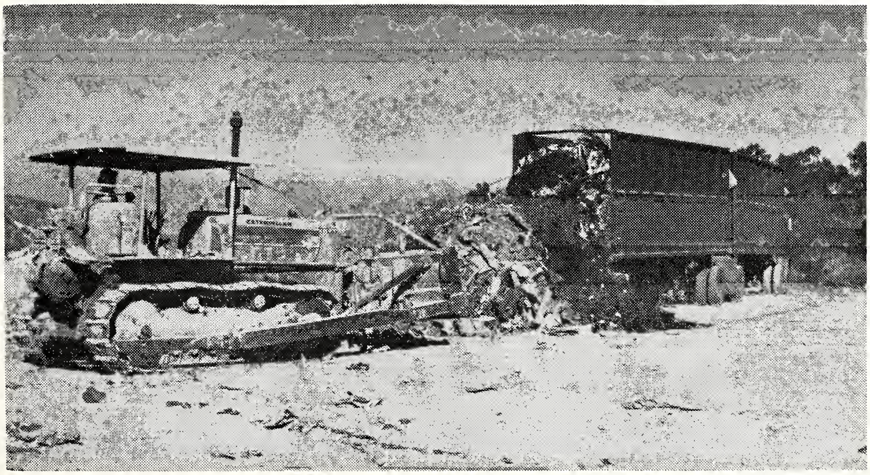


Fig. 29. The cost of hauling refuse to a disposal site is important in the selection of a disposal method. Some cities that have sanitary landfills use large collection trucks, which haul the refuse to a transfer station where it is put into tandem trailers (above). The trailers haul the refuse to the site of the fill, where they are unloaded (below). These pictures are of the Los Angeles County Sanitation Districts' transfer station and landfill.



is also used for other municipal services, such as snow removal, the costs must be prorated.

Special equipment, although initially expensive, may actually lower hauling costs—particularly those for long hauls. Transfer trucks, for instance, sometimes carry refuse collected by as many as six route trucks from the transfer point to the disposal facility, which cuts down on the number of trucks making the complete haul and frees the route trucks for other collections.

Problems of Long Hauls. Although most refuse is hauled to disposal facilities during off-peak traffic hours, the last trips of the day often coincide with evening rush hours, increasing congestion and the chances of accidents and annoying the public—factors that favor short hauls.

Other objections to long hauls are that more of the public are aware of the collection trucks. Regardless of how good the equipment is, it is difficult to keep refuse collection vehicles clean and odorless and to prevent papers and other objects from blowing or dropping off of them.

Special Disposal Problems

Special disposal problems arise no matter what kind of collection and disposal methods are used in a city. The unusual must therefore be anticipated, since special disposal problems often require special solutions.

Problems become "special" primarily because of size or infrequency. Disposal of household refuse is routine even with seasonal and other changes in quantities and kinds. But if disaster strikes it may be necessary to change the routine radically and call in outside help. Moreover, some cities, because of geographical location, characteristics of the economy, or because of unusual construction programs have other special problems.

Disposal problems are of two kinds: those caused by employees, equipment, operating procedures, or the method of disposal used; and those that result from a disaster or because of an unusual or especially hard-to-handle type of refuse. Only the second kind is considered here.

Refuse from Disasters

Not every disposal problem caused by a disaster can be anticipated and planned for, of course, but there is a continuing need for a reasonable measure of preparedness. Reserve capacity at disposal facilities is not the whole answer. Resourcefulness and ingenuity is needed in meeting such problems.

If a tornado, earthquake, or hurricane strikes a city, the refuse disposal agency cannot always handle all of the additional refuse that results. The police and fire departments, safety experts, and public health agencies often help—sometimes by waiving regulations temporarily so that refuse and debris can be disposed of quickly to prevent fire, accidents, and outbreaks of disease. Heavy construction equipment is often used to clear streets and roads and to cut up trees and branches so they can be disposed of. In a major disaster, state agencies often call in federal agencies such as the Office of Civilian Defense and the Army Corps of Engineers.

Condemned Foods

Federal, state, and local health agencies have the authority to condemn foods for human consumption, which, after condemnation, must be disposed of, usually by city agencies.

Federal agencies, under interstate commerce laws, are concerned with foodstuffs that are taken across state lines. The states may and do quarantine infected hogs and diseased plants and fruits. Local health officers may also prohibit the sale of foodstuffs spoiled in transit or kept too long in storage. In any event, all such agencies must work together in condemnation of spoiled foods or infected animals and plants.

Regardless of the method used to dispose of condemned foods, it is desirable that a representative of the condemning agency witness the destruction of the food to be sure that it is not sold or used by the people handling it. A simple treatment, such as spraying with kerosene, is sometimes used to prevent "expropriation" of condemned food before it is disposed of.

Seaport cities probably have bigger problems with condemned foods than inland cities. Sometimes all of the foodstuffs brought in by a single ship must be destroyed. If fire or water has damaged labels on canned goods, they cannot be sold even though the contents are undamaged.

Foods condemned on a ship or other carrier must be disposed of quickly to prevent delaying the operation of the ship, while foods condemned in a warehouse can usually be taken to a disposal facility in quantities and at times that will not interfere with normal disposal operations. Thus a landfill, which is flexible in its capacity and operation is often the simplest way of disposing of large quantities of condemned foods.

If canned foods are disposed of by incineration, each can must be punctured to prevent it from exploding. If canned foods are disposed of by grinding them and flushing them into the sewer system, each can must be opened and only the contents put in the grinder.

Many foods condemned for human consumption are safe for hogs, but if they are to be fed to hogs, health officials must first give their approval.

Hazardous and Special Refuse

Explosives and inflammable materials are easily recognized as hazardous; others, such as highly alkaline or acidic liquids and toxic wastes such as manganese, magnesium, and cyanides are not as easily identified but can cause damage. Some kinds of refuse also expose collectors and handlers to disease.

Many hazardous wastes come from manufacturing businesses. For the most part, the city disposal agency knows about them and makes arrangements with owners of plants and factories to dispose of the wastes, either at municipal or private facilities. Toxic wastes can be disposed of in carefully controlled sanitary landfills in isolated areas. Waste oil is a problem in some areas. Some cities pond it and burn it at night; others accept it in open ponds at designated sanitary fills. A special charge is usually made for disposal of such wastes.

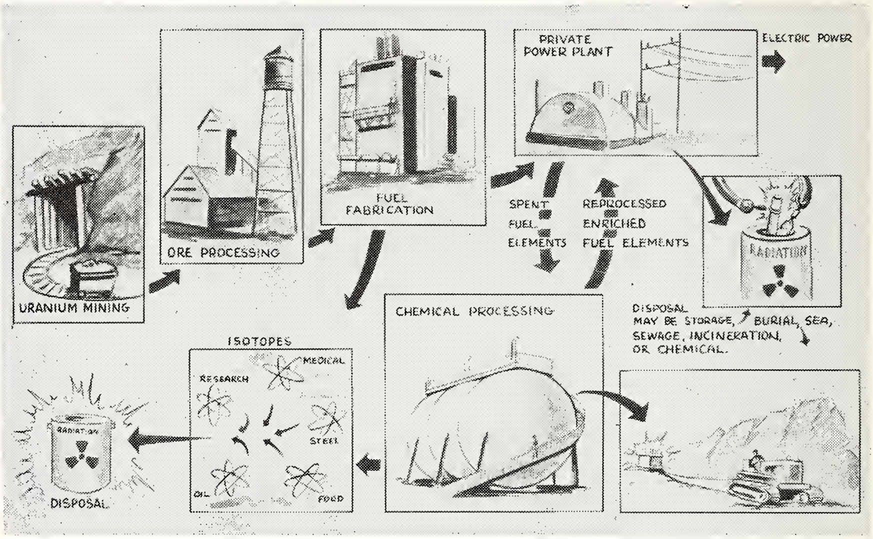

URANIUM MINING
ORE PROCESSING
FUEL FABRICATION
PRIVATE POWER PLANT
ELECTRIC POWER
SPENT FUEL ELEMENTS
REPROCESSED ENRICHED FUEL ELEMENTS
RADIATION
CHEMICAL PROCESSING
DISPOSAL MAY BE STORAGE, BURIAL, SEA, SEWAGE, INCINERATION, OR CHEMICAL.
ISOTOPES
MEDICAL
RESEARCH
STEEL
OIL
FOOD
RADIATION
DISPOSAL

Fig. 30. Radioactive wastes come from a variety of sources, as shown here. Although the disposal of such wastes in 1961 was still the responsibility of federal agencies, disposal of some of them may become the responsibility—and a special problem—of municipalities in the future. (Reprinted by permission of Business Week.)

Pathological wastes from hospitals and other institutions should be incinerated at the source. If they are handled at a municipal incinerator, extreme care is required to prevent workers from becoming infected.

The growing use of radioactive substances in government and industry is producing ever-increasing quantities of dangerous wastes that cannot be handled as other refuse. Although by early 1961 no municipality was routinely disposing of such substances, it is possible that cities will be required to do so in the future.

Industrial Wastes

Refuse produced by industrial and manufacturing plants is as varied as the raw materials that go into the products manufactured. A good many of the materials that once were "waste" are now by-products, but wastes that are not used as by-products must be disposed of.

Plastics, rubber goods, battery boxes, tar paper, and other refuse that is highly volatile can be disposed of at ordinary incinerators in small quantities. However, if there are large quantities of such materials, they must be burned in special furnaces equipped with after-burners and devices to prevent excessive smoke emissions.

Trash burners are used in some industries—particularly woodworking plants. In addition, landfills are sometimes used to dispose of industrial wastes. (See the section on industrial wastes in Chapter 1.)

Construction Wastes

Construction wastes—whether from new building or repairs—are usually nonputrescible and can frequently be burned or put in landfills.

In large cities there is often so much construction refuse that it is necessary to use private dumps and landfills. In such cases, private collectors usually handle the refuse. (See Chapter 1.)

Demolition Wastes

In most large cities, quantities of wastes resulting from the demolition of old buildings torn down to make way for commercial buildings, housing projects, expressways, and community facilities must be disposed of by the wreckers or by the city.

Some of the materials are salvageable, depending on the type of construction, the local market for the materials, and the urgency for completing the demolition job. But even when conditions for salvage are ideal, more than half of the materials in a building have no value.

A large part of a demolished masonry building is rubble which can be used as solid fill material. It is often given away or sold for use in fills on private property or is used in road construction for subgrade. It can also be used for temporary access roads on landfills.

The combustible wastes, mainly wood and asphaltic materials, pose the big problem. The least expensive solution is to burn them on the demolition site. However, many cities prohibit open burning in populated areas. An alternative is to haul the material to a point within economical trucking distance where it can be burned without creating a nuisance or endangering lives or property. Open burning of demolition wastes—or any other refuse—in any location is rapidly falling into disfavor because of the increasing emphasis on control of air pollution.

Landfills are another means of disposing of demolition wastes, but they are not particularly satisfactory because of the poor compaction of the refuse. Some cities also report considerable damage to landfill equipment from demolition wastes. In areas in which it is permitted, controlled burning of such materials in an "as received" condition can be done with little nuisance and hazard at landfill sites, using specially constructed but inexpensive burning pits. Conical burners made of steel can also be used at landfill sites for bulky wastes and miscellaneous refuse.

Some cities along the seacoast find it advisable to permit burning of demolition lumber and other bulky wastes on steel barges anchored at strategic points a safe distance from land. Burning is often done when the wind is off-shore.

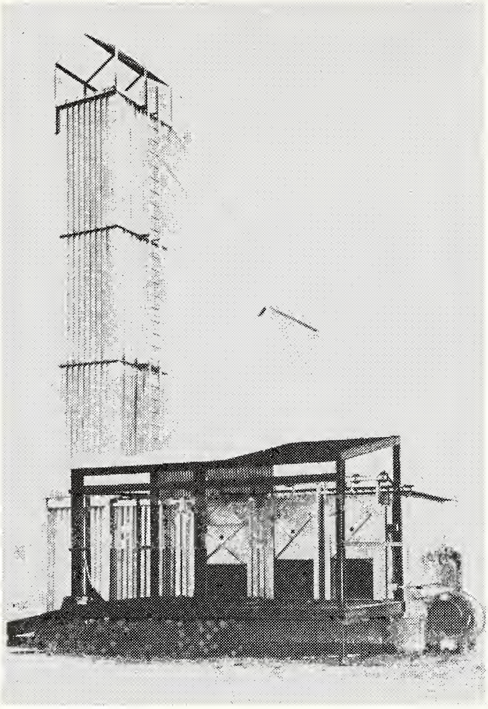


Fig. 31. Disposal of industrial wastes can be a problem for cities, but many industries dispose of such refuse on the premises. This on-site incinerator built for a rubber company in Willoughby, Ohio, can burn 1,000 pounds of rubber wastes or 1,200 pounds of dry wastes an hour.

See the section on the APWA studies of quantities and types of refuse in Chapter 2 for figures on the amounts of demolition refuse produced in cities today.

Dead Animals

Several means are used to dispose of dead animals—dogs, cats, chickens, and others. (See Chapter 2 for kinds and quantities of animals that must be disposed of.)

Large central grinders are used in some cities. Only one-stage grinding is necessary. A 150-horsepower hammer-type grinder will handle animals up to 150 pounds, and larger animals can be cut into pieces before they are put in the grinder. The grinder may be installed at the sewage treatment plant or on an interceptor sewer. It can be made semi-automatic so that the collection crew can dispose of the animals. The grinder and flushing water are started by pressing a button, and the crew can run the unit for two minutes or so after the last animal is disposed of to wash the equipment.

Dead animals can also be disposed of at rendering plants. However, the number of rendering plants has decreased in recent years because of a decreasing market for their products. And many plants will not accept dead animals collected from streets during the summer.

Other cities bury dead animals in special trenches at landfill sites, but the method is not considered a good one for large cities. Still others burn them in incinerators.

A problem unique to coastal cities is that of large dead marine animals such as whales and sea lions that are washed ashore. Some cities dynamite the bodies, placing the charge so that the dismembered animals are blasted back into the water.

See *Refuse Collection Practice,* pages 260 and 261, for a list of 77 cities and the methods they use to dispose of dead animals.

Automobiles

Automobile bodies can be burned in specially designed incinerators and the metal salvaged and sold. One kind of incinerator used for this purpose is described in Chapter 6, On-Site Incineration.

A small refractory-lined incinerator that can be constructed locally has been designed to burn only a few cars a day—up to 30. One or two cars can be burned in it at a time.

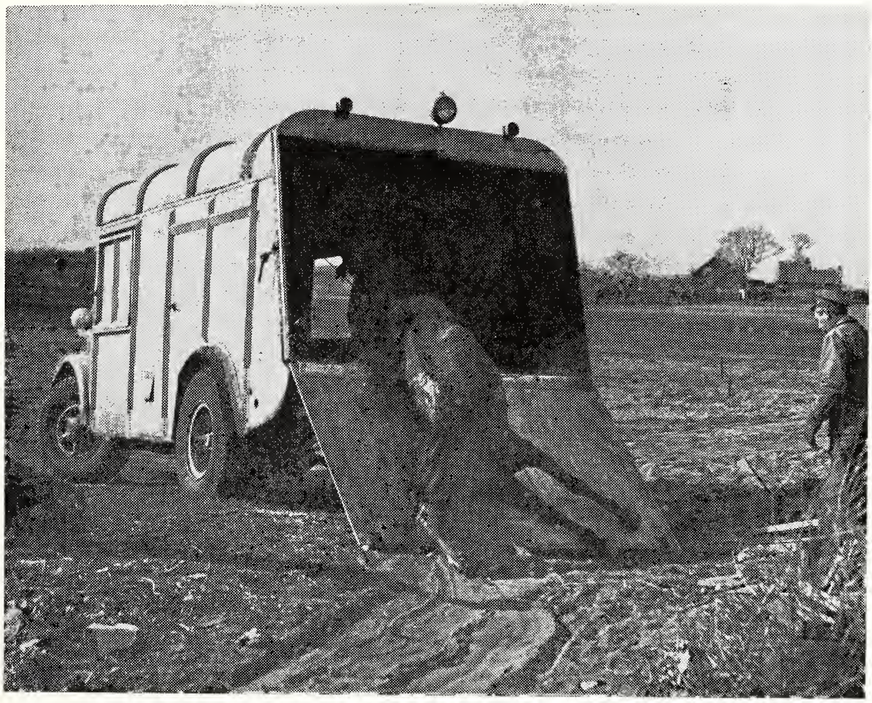


Fig. 32. Disposal of large dead animals is a special problem, even in large cities that are usually equipped to handle them. The bodies can be buried, sent to a rendering plant, burned in an incinerator, or ground in large grinders.

Car bodies can also be disposed of by putting them into a large baling press and compressing them until they are about 2 feet by 4 feet by 5 feet. The baled cars are sold to steel mills as salvage material.

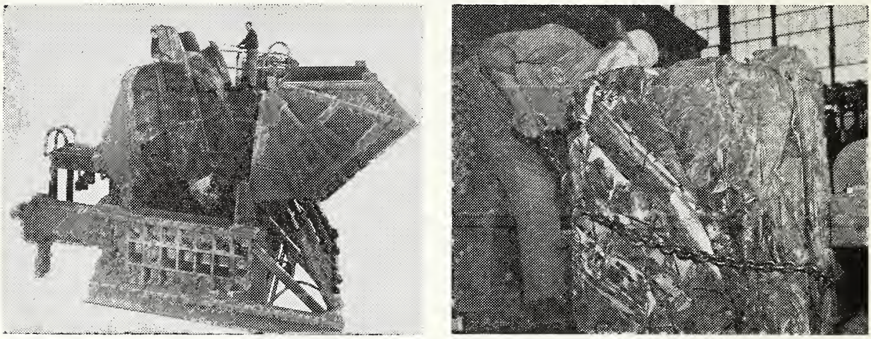


Fig. 33. Automobile "graveyards" are common near cities, although the metal can often be sold for scrap—if it can be shipped. The baling machine (left) compresses a whole car body to a small bale (right).

Leaves and Trees

Leaves, boughs, and tree trunks are difficult to dispose of because they are difficult to burn and are large and bulky. Boughs and trunks are sometimes cut into small pieces with a wood chipper and either burned or put into a sanitary landfill. A portable, multiple-chamber, on-site incinerator has been found to be practical for burning such refuse. Leaves are usually taken to landfills and dumps for disposal, but some cities permit burning of them on the streets, some burn them in incinerators, and some give them away or sell them for humus. Although leaves are burned in incinerators in some cities, furnace operators say they are difficult to burn and it is costly to do so. Leaves—even dry ones—must be stirred frequently as they have a tendency to smother the fire rather than increase combustion.

Contract Disposal Services

Although the trend in recent years has been toward municipal operation of refuse collection and disposal services, some municipalities contract with private companies to provide collection or disposal services —and sometimes both. Many cities have changed from contract services to municipal services because they find municipal services are cheaper and because the city can recruit well qualified employees and provide better services than private companies. However, others have been forced to discontinue contract disposal because changing conditions have made it unprofitable for the contractor. For instance, disposal of garbage by feeding it to hogs once was a common contract disposal method. When the states required that all garbage fed to hogs be cooked, however, many hog raisers quit using garbage as feed because the method was too expensive. The result was that some cities could no longer contract for garbage disposal. Today commercial and industrial refuse is more frequently disposed of by private contract than other kinds of refuse.

Local governments of various sizes contract for disposal—San Francisco; Seattle; Rockford, Illinois; Clifton, New Jersey; and St. Louis County, Missouri, for example. Private disposal companies use some of the same disposal methods that municipalities use—landfills and incineration, for instance; and some that municipalities do not use—rendering and dehydration, are examples.

The results of a questionnaire survey conducted in 1958-1959 by *Public Works* magazine indicated that more than 350 municipalities in the United States contract for collection of refuse and many also contract for disposal.

The City of Seattle has used the contract method of collection and disposal satisfactorily for a number of years, and has developed a comprehensive ordinance, proposal, specifications, and contract for its contractual services. They are reproduced as Appendix C.

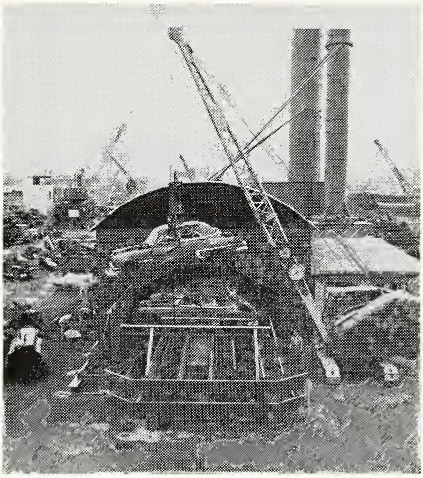
Advantages and Disadvantages

The bases on which a city decides whether to use contract disposal services are costs and efficiency. Although the contractors are in business to make money and the city is obligated to see that refuse is disposed of as cheaply as possible consistent with efficiency and good health and sanitation practices, the two interests are not necessarily conflicting.

There may be circumstances in which a city is forced, at least temporarily, to use contract disposal regardless of cost and efficiency, however. For instance, private companies may own all the suitable sites for sanitary landfills or own the only incineration plant that can meet disposal emergencies.

Whether contract disposal is economical for the city depends on local circumstances. Under contract disposal, the major direct expenditures are to the contractor and to city employees for regulatory and inspection services. Even if only part of the refuse is disposed of under contract, capital expenditures for sites, buildings, and equipment are reduced, which may be an important factor if other capital improvements are more urgently needed. Furthermore, administrative and overhead costs are reduced, and the city government is relieved of day-to-day operating problems. On the other hand, if there is not strong competition between contractors there is no incentive for them to keep charges low; and if short-term contracts are written, the contractor's costs for amortization of plant and equipment may be too high to permit reasonable charges. Furthermore, if municipally operated services are as efficient as private services, they may be more economical because the city does not make money on its service.

The contractor is sometimes—although certainly not always—more efficient than the municipality in its operations. Because the contractor is



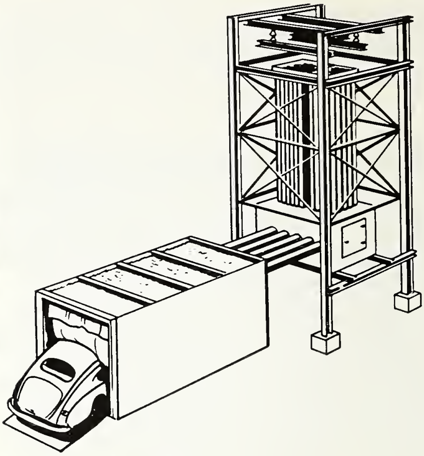


Fig. 34. Combustibles can be burned from car bodies without causing unpleasant smoke and fumes by using special incinerators. The picture left is of one known as the "Pyrocleaner-200"; the drawing right is of a "Smokatron" burner that is said to process two car bodies an hour without violating air pollution control ordinances.

out to make a profit, he is more impelled to get "an honest day's work for an honest day's pay" than some municipal governments. He frequently is able to act more quickly in an emergency (because he is not impeded by red tape), such as a hurricane or flood, that requires special equipment and overtime work. Furthermore, if equipment is out of order, he is freer to rent or make other arrangements for substitutes until his own is operating. In fact, his contract may require that he do so.

On the other hand, the profit motive may make the contractor cut corners and reduce the quality of services to the public; his contract may be too inflexible to permit him to meet changing conditions; he may have financial difficulties that are reflected in poor services; and he is more vulnerable to strikes than municipalities. In addition, he may get his contract through "politics" and because of political influence he may not be required to perform the services reasonably and efficiently.

Contract Provisions

If a city decides to contract for even part of its disposal services, it must draw up specifications for the service so that all who are interested can bid on an equal basis. But before the specifications are drawn up, the conditions under which a contractor will operate must be fully analyzed. Careful estimates must be made of all costs under ordinary circumstances and contingencies and emergencies must be planned for.

Contract services often include both collection and disposal and the contract and the regulations governing the services should be spelled out so that the municipality, the contractors, and the public understand them.

Health, sanitation, and convenience for the public are the most important considerations of the city.

The term of the contract is important. If contract disposal is new to the city or if the city wants to encourage new bidders, the time the contract runs should be long enough so that companies new in the business can reasonably expect to amortize capital costs. If a city is prohibited by law from writing a contract that is long enough to cover amortization of plant and equipment, the city may be able to arrange for lease or purchase of the facilities at the end of the contract period or to include provisions for extension of the contract if the services are satisfactory. Renegotiation of a contract is also possible.

The contract should provide that the city has control over labor practices: wage increases should be stated in the contract on the basis of a predetermined scale; wage kick-backs from employee to employer should be prohibited and penalties set; and provisions on discrimination because of race, creed, color, and union affiliation should be included.

Increased payments to the contractor to take care of increased operating costs and increased amounts of refuse handled should be provided for in the contract, as well as provisions for controlling salvage of refuse that has resale value.

Enforcing Contract Provisions

Contracts for disposal should include penalties if the contractor fails to perform the services contracted for or performs them inadequately. Prevention is better than cure, however. If inspections or complaints disclose inadequate services, city employees can sometimes see that they are corrected by warning the contractor or helping in other ways. However, if there are widespread and frequent breakdowns in service, city officials are obligated to penalize the contractor, as provided for in the contract.

Regulations for the Public

Regulations for the kinds and locations of refuse containers, for the ways in which refuse is to be separated, and for sanitary conditions to which householders and businesses must comply should be drawn up and enforced by the city. The city should also be responsible for informing the public of the regulations. In addition, city officials should investigate a contractor's complaints about the public and enforce the regulations if necessary.

Adaptability of Method to Changing Conditions

It is important that the primary methods of disposal that a city uses be adaptable to expansion, modification, or conversion.

The number of people in a city changes, people move to outlying areas, standards of living change, and new industries and businesses start up, all of which change the amounts and kinds of refuse that must be disposed of. Furthermore, the kinds of services needed in one part of a city may be different from those needed in another. Industrial areas may require one kind of disposal, business another, high-density hotel and residential areas another, and low-density residential areas still another.

Although it is impossible to accurately predict where and to what extent such changes will occur, reliable information on trends and future developments is available and should be studied in relation to location and size of disposal facilities. The local planning agency, utilities companies, and business associations are usually able and willing to provide data.

If, for instance, one or both of the two most common disposal methods —landfills and central incineration—are decided upon, sites should be selected that will best serve present and predictable future needs. The site for an incineration plant should be big enough so that the plant can be enlarged if necessary, or a second site should be selected for an additional plant in an area that can reasonably be expected to need one in the future. The same is true of landfill sites.

On the other hand, in an area that is zoned for single-family houses and is to be so developed, household garbage grinders will probably be common. The type of disposal facilities needed for that area will differ from those for an area slated for renewal in which large apartment buildings will be built.

In any event, all of the reliable data for predicting future needs should be analyzed before a decision is made on methods and the location and size of the disposal facilities.

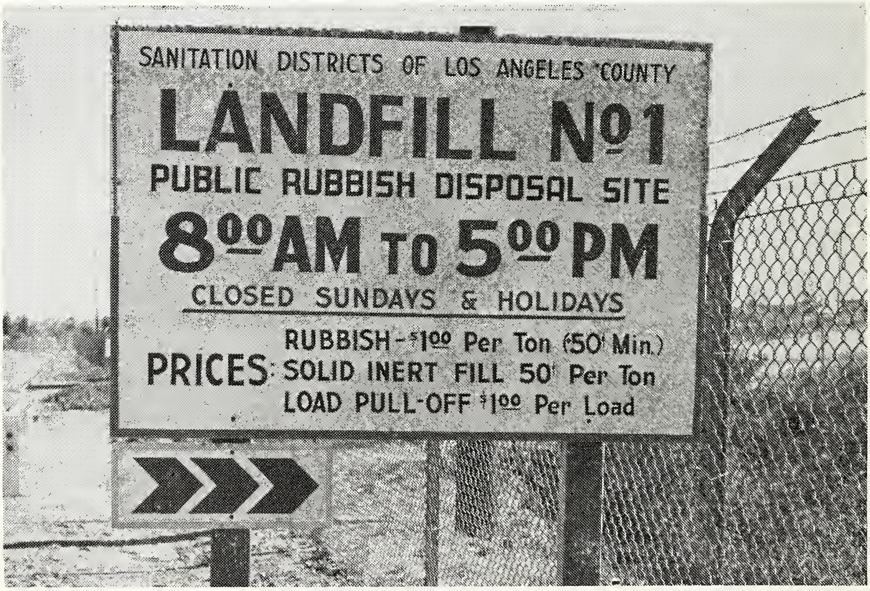

SANITATION DISTRICTS OF LOS ANGELES COUNTY
LANDFILL Nº1
PUBLIC RUBBISH DISPOSAL SITE
8^{00}AM TO 5^{00}PM
CLOSED SUNDAYS & HOLIDAYS
PRICES: RUBBISH - \$1^{00} Per Ton (50¢ Min.)
SOLID INERT FILL 50¢ Per Ton
LOAD PULL-OFF \$1^{00} Per Load

Fig. 35. An easily read sign, a good fence, and a program of public education are needed to assure that rules of operation for a landfill are obeyed.

Hours Disposal Facilities Are Operated

The city must determine whether its disposal facilities will be operated 8, 16, or 24 hours a day, 5, 6, or 7 days a week.

Large cities often operate incineration plants on a 24-hour basis, which permits haulers to deposit refuse at any time. If the facility is not open 24 hours a day, "sneak dumpers" are encouraged to leave odorous or unsanitary refuse in lots, alleys, and along streets and roads.

However, landfills and incinerators can often be operated more efficiently if refuse is received only at fixed times. If it is, workmen can keep the premises cleaner and more attractive by tidying up after the last refuse loads of the day are received. A fence with gates that can be locked and prominently displayed signs giving the hours that refuse is received help enforce regulations.

Influence of Salvage Operations on Methods

Salvage operations can be a part of many refuse disposal methods—landfills, central incineration, composting, and central grinding. Whether they are profitable to a municipality or whether the nuisances and hazards they create outweigh the advantages must be considered before salvage is decided upon even as a partial method of disposal. The problems of salvage operations and their advantages and disadvantages are discussed in Chapter 10, Salvage and Reclamation.

Public Acceptance of Methods

Acceptability of a method of refuse disposal by the public is of primary importance, since the choice of methods may well hinge upon how easy it is to get approval of it. The public is more likely to disapprove of a method because it believes it will create nuisances than for any other reason.

Public Information Program

To gain acceptance of a proposed refuse disposal method, a program of public information is often necessary. The need for sanitary and efficient disposal methods should be made clear to the public. Especially in large cities, the residents may have little or no idea of what becomes of refuse after it is loaded on collection trucks. The time-worn adage, "out of sight, out of mind" is true of most residents as far as refuse is concerned.

Leadership in an information program may originate in the city council after its members and other community leaders are acquainted with local refuse disposal problems. City officials can begin their own study of the problems by inquiring into commonly used collection and disposal practices. They can visit disposal sites, inspect collection equipment, study the problems of collection methods, and gather other factual data. The study should be made in an atmosphere of inquiry, however, with as little interpretation as possible and with judgment on methods deferred until the study is complete.

While this is difficult and requires considerable time, it pays dividends. Too often facts are lost in a whirlwind of arguments over interpretation, suggestions for solutions to refuse problems based on little or inaccurate information, opposition to sites, explanations of how a system works, who is to blame for present inadequacies, and financial problems. If the council members learn the facts before attacking problems in which differences of opinion are almost certain to develop, however, a solution to disposal problems and public support for it can be achieved.

The advice of interested groups should be sought and data on the success of various disposal methods used in other communities should be collected and made available in nontechnical terms to community leaders and interested citizens. Since there are many facets of the refuse disposal problem that must be considered, the public cannot be expected to understand the problems and solutions and to concur in a decision in too short a time.

A series of feature articles in local newspapers, relating the progress of the study and the preparation of a report on it, is an effective way of informing the public and providing a basis for understanding and evaluating the proposal. Concurrence of health authorities and of the medical profession should be sought and differences of opinion resolved as far as possible before public hearings are held. Premature and irresponsible statements on costs and the technical merits of various methods should be avoided. Too often the public hears first the conflicting opinions of public officials—opinions formed even before engineers have begun an objective study of the problems and solutions.

Public Demands for New Methods

The initiative for different methods of refuse disposal does not always come from public officials. Frequently it comes from a segment of the public that demands action to alleviate conditions that it finds intolerable. Such action does not necessarily imply concern with the over-all problems of disposal or lack of concern on the part of the public officials. Often it stems from opposition to uncontrolled subdivision of land near a refuse dump, a farm on which hogs are fed garbage, an obnoxious industry, or some other enterprise unsuited to an urban area. Residents of a new subdivision near a dump, for example, may try to get dumping stopped. The outcome may be a long overdue improvement in all local refuse disposal procedures.

Demands for improved refuse disposal methods also come from larger segments of the public than neighbors of a dump, incinerator, or landfill. Smoke or other air pollution or lack of provision for disposing of all kinds of refuse may result in protests. If so, enough of the public may be ready to accept new methods of refuse disposal so that officials can carry out plans without delay.

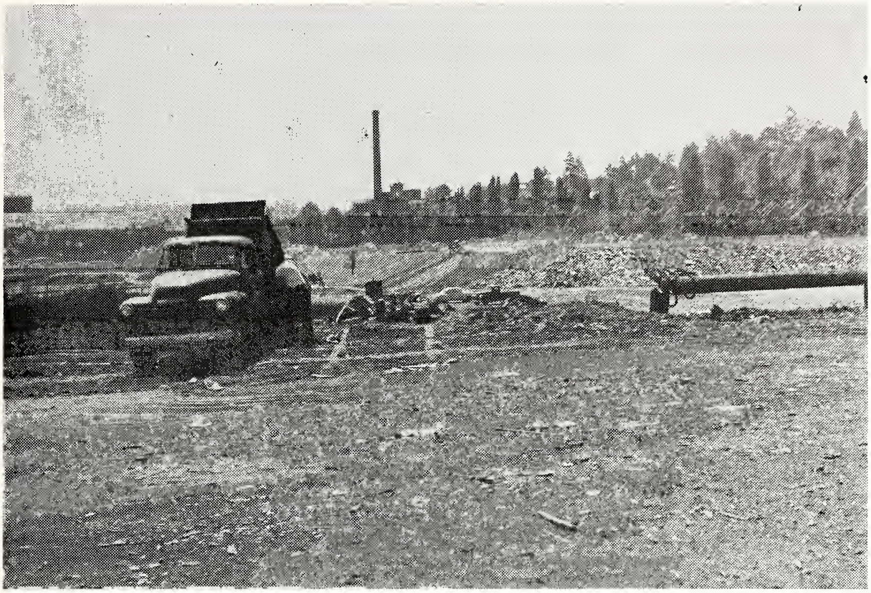


Fig. 36. Private contractors operate many sanitary landfills satisfactorily. Ravenna fill in Seattle is an example.

Public confidence in city officials, community leaders, and health authorities is important in acceptance of any refuse disposal method. An up-to-date and more adequate disposal system often appears to be more costly than the old one, and since most people cannot be well informed on costs and technicalities, they must rely on community leaders to give them correct information. Some people, of course, will oppose any solution that the majority of the public and public officials find acceptable. Such opposition usually grows out of personal prejudices or vested interests, although sometimes it is based on a sincere belief in an untried and perhaps unpromising disposal method.

Ability and Willingness to Pay

Regardless of where the impetus for change comes from or by whom a change is opposed, the public must be able and willing to pay for the methods decided upon. It is often necessary to convince the people that what is on the face of it a cheap disposal method is in reality an expensive one—in dollars and cents, in health and sanitation problems, in lack of convenience and aesthetics. Once they are convinced that an initially expensive method will bring advantages, they are usually willing to pay for it.

After a new method of disposal has been adopted it is extremely important that the system be operated as efficiently and with as much regard for appearance of the disposal facilities as it is possible. The public must be able to *see* that the new method is an improvement.

4 SANITARY LANDFILLS

Dumping on land was probably the first refuse disposal method used, perhaps because it was the most convenient. As civilization developed and people gathered together in greater and greater numbers, the practice of indiscriminate dumping underfoot became increasingly unsatisfactory. Although the public health aspects of refuse disposal have been recognized only recently, some time ago the quantities and the offensive nature of refuse had created conditions in most cities that were unsatisfactory to all. And so the objectionable dumping grounds were moved from populated areas and more isolated sites were found. Long hauls proved to be costly as well as inconvenient, however, and even in areas where only a few people lived, violent objections were raised to dumps.

There were, however, areas within most cities or near their boundaries that could be put to good use if they were filled. Getting and transporting earth fill to those sites was often prohibitively expensive, but refuse could be used effectively and much more economically, although it was necesary to fill the areas without creating nuisances and endangering the public health. A number of cities developed successful methods—primarily simple burial—of using the garbage component of refuse as fill many years ago: Champaign, Illinois, in 1904; Columbus, Ohio, from 1906 to 1910; and Davenport, Iowa, for some years before 1916. In Davenport, a method of mixing and covering the organic refuse with a sufficient quantity of inert materials such as earth or ash was used to minimize odors in an area being reclaimed along the Mississippi River. At the same time, similar procedures were being tried in England and Germany.

In the 1930's several cities in the United States experimented with heavy equipment to compact the refuse, thereby saving space and developing a means of disposing of refuse on land in an economic, as well as sanitary, manner. One city was New York, which badly needed a different method of refuse disposal, since it was faced with court action initiated by coastal cities in New Jersey to force cessation of dumping its refuse at sea. (In 1933, the United States Supreme Court upheld a ruling requiring that New York City cease this practice.[1])

It was during this period, apparently, that the term "sanitary landfill" was coined at another pioneering operation in Fresno, California, where the "cut and cover" or "trench" method of landfilling was first used in the United States. The term is appropriate, since land is filled with refuse in a sanitary manner.

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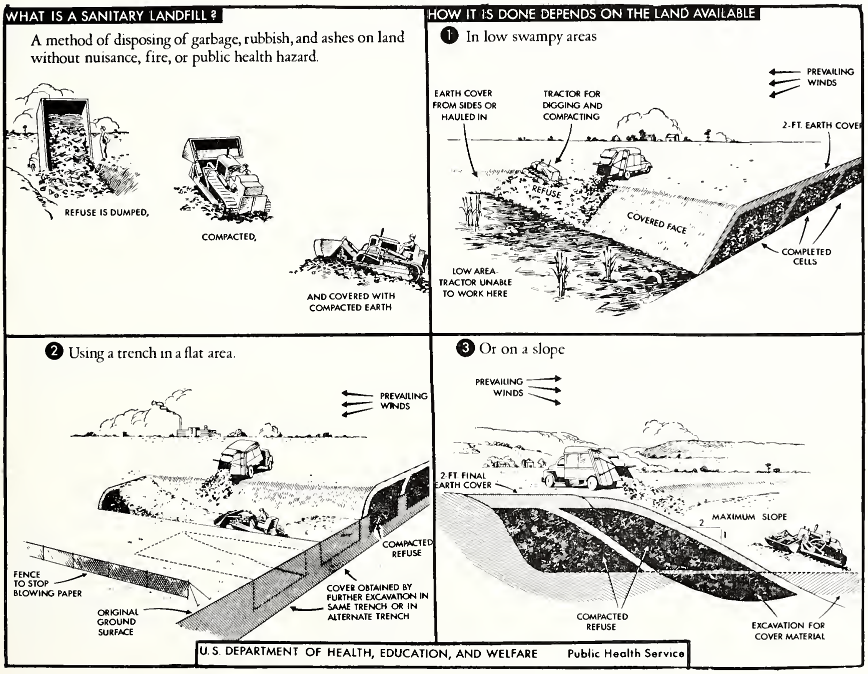
[1] *New Jersey* v. *City of New York,* 290 U.S. 237 (1933).

During the early part of World War II, the Army was faced with the need to develop an economical and sanitary method of handling rapidly changing amounts of solid waste at camps and other installations. Studies revealed the adaptability of a piece of equipment called a "bullclam," which could not only compact the refuse but also pick up and carry earth cover. At the same time it was found that other equipment such as front-end skip loaders and, on large operations, draglines and scrapers could also be used successfully. So the sanitary landfill was recommended as a method of refuse disposal at military installations in the United States.

The successful use of the method by such cities as Fresno and New York, as well as by the Army, influenced the adoption of it by many municipalities. By the end of 1945 almost 100 cities in the United States had adopted it and by the beginning of 1960 more than 1,400 cities were reportedly using it.

Recently, however, use of the method has had to be curtailed in a number of large cities, including New York and Baltimore, because of the difficulty of finding suitable sites within economic haul distances and because of the need to preserve sites for disposal of noncombustibles such as ashes and incinerator residue. Nonetheless, the sanitary landfill method of refuse disposal will continue to find users among small cities and, for that matter, some large cities, at least until a more economical and sanitary method is devised.


WHAT IS A SANITARY LANDFILL ?
A method of disposing of garbage, rubbish, and ashes on land without nuisance, fire, or public health hazard.
REFUSE IS DUMPED,
COMPACTED,
AND COVERED WITH COMPACTED EARTH
HOW IT IS DONE DEPENDS ON THE LAND AVAILABLE
❶ In low swampy areas
PREVAILING WINDS
EARTH COVER FROM SIDES OR HAULED IN
TRACTOR FOR DIGGING AND COMPACTING
2-FT. EARTH COVE
REFUSE
COVERED FACE
COMPLETED CELLS
LOW AREA TRACTOR UNABLE TO WORK HERE
❷ Using a trench in a flat area.
PREVAILING WINDS
COMPACTED REFUSE
FENCE TO STOP BLOWING PAPER
COVER OBTAINED BY FURTHER EXCAVATION IN SAME TRENCH OR IN ALTERNATE TRENCH
ORIGINAL GROUND SURFACE
❸ Or on a slope
PREVAILING WINDS
2-FT FINAL
ARTH COVER
2
1
MAXIMUM SLOPE
COMPACTED REFUSE
EXCAVATION FOR COVER MATERIAL

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE Public Health Service

Fig. 37. There are various methods of operating sanitary landfills. How it is done depends mostly on the kind of site available.

Site Selection

Site selection is the process of locating and obtaining the use of suitable land; it is the most important of the pre-operational steps in developing a satisfactory landfill program.

If possible, sanitary landfill sites should be provided for in the comprehensive plan of a city. And it is at times advantageous to buy up sites for landfills at the same time a site for a sewage treatment plant or a sewage lagoon is bought.

Many factors must be evaluated to determine suitability of a site for a landfill. The persons responsible for determining suitability must have knowledge of the public health and nuisance problems of uncontrolled disposal, good operational procedures, the capabilities of the equipment to be used, topography, special climatological problems, drainage, the future use of the land, what roads will facilitate access to the site, availability of acceptable cover material, location with respect to residences and industry, the average length of hauls for collection vehicles, the possibility and significance of underground or surface water pollution, zoning regulations, and whether a site is likely to win public acceptance. Also necessary is a thorough knowledge of the immediate, as well as the long-range, limitations of this method of disposal. These factors are discussed here only briefly; they are elaborated on in other sections of the chapter.

Public Health and Safety

Although the sanitary landfill as a method of refuse disposal was given a clean bill of health many years ago, its acceptance by the public is still far from unanimous. The public has too often heard the terms "landfill," "dump," and "sanitary landfill" used interchangeably and does not understand the difference between a *sanitary* landfill and a landfill or dump.

A well located, well designed, and efficiently operated sanitary landfill meets public health standards and requirements for control of air pollution, fire, and nuisances:

1. Vector breeding or sustenance is prevented by eliminating harborage and food supply for rats, flies, and other vermin.
2. Air pollution by dust, smoke, and odor is controlled.
3. Fire hazards are controlled during operational phases. (They are negligible in a completed fill.)
4. Pollution of surface and ground waters is precluded.
5. All nuisance factors are effectively controlled; i.e., the system is aesthetically acceptable and noise is kept to a minimum.

The United States Public Health Service with the APWA in 1957 developed standards by which sanitary landfills can be rated. Three classifications—A, B, and C—were set up. Landfills rated in the A and B classifications are satisfactory and those in the C classification unsatisfactory. Local conditions determine whether the Class A or B type of operation is warranted. Specifically, the standards for each are:

A. Operated without public nuisance or public health hazard; covered daily and adequately; no deliberate burning practiced.

B. Operated without public nuisance or public health hazard, but location permits modification of "A," such as certain types of wastes are burned at site, or the fill is covered only three times weekly.

C. Operating techniques permit development of public nuisance and potential public health hazards, such as fly breeding, rodent sustenance, odors.

St. Louis County, Missouri, in 1953 passed a comprehensive refuse disposal ordinance that reflects the recommendations of sanitary engineers and sets high standards for operation of sanitary landfills. It is reproduced as Appendix C.

Land Requirements

A rule of thumb for land requirements is that from ¾ to 1½ acres of land (an average of 1 acre) is required for each 10,000 persons in the city for 1 year of operation if the depth of compacted refuse is to be about 7 feet. Sanitary fills may, however, be used to fill deep depressions by using layers of fill of 10 to 15 feet each, reducing land and cover material costs sufficiently to make the method economical. A method of calculating the life expectancy of a fill site is described in the Engineering Survey section of this chapter.

Topography

Depressed areas such as ravines, swamps, and abandoned borrow pits in which the grade must be raised are usually considered topographically and economically suitable for sanitary landfill sites, providing the fill operations are so conducted that proper surface drainage is maintained.

Availability of Cover Material

The type of earth cover available on a site should be determined by test borings. The most desirable is a sandy loam, free of stones bigger than 6 inches in diameter. The cover material may be excavated on the site or hauled in from borrow pits. Cover material also has been economically procured in New York for sites adjoining large bodies of water by hydraulic dredging. A clamshell or dragline is sometimes used on sanitary landfills to excavate suitable earth fill from below water level. Unfortunately, ideal cover soil on the site is the exception rather than the rule.

Proximity to Residences and Industry

Although sanitary landfills have been successfully operated in areas adjacent to residences, institutions, and industry, they frequently are expensive and often cause troublesome public relations problems.

A site close to a residential area may be justified, however, not so much because it is cheaper to buy than another site, but because the sanitary fill will actually improve the site itself. The public is usually concerned with health, nuisance, and safety problems and with the possibility that the neighborhood in which a landfill is to be located will depreciate. Proper operation of a fill and emphasis on how the site will eventually

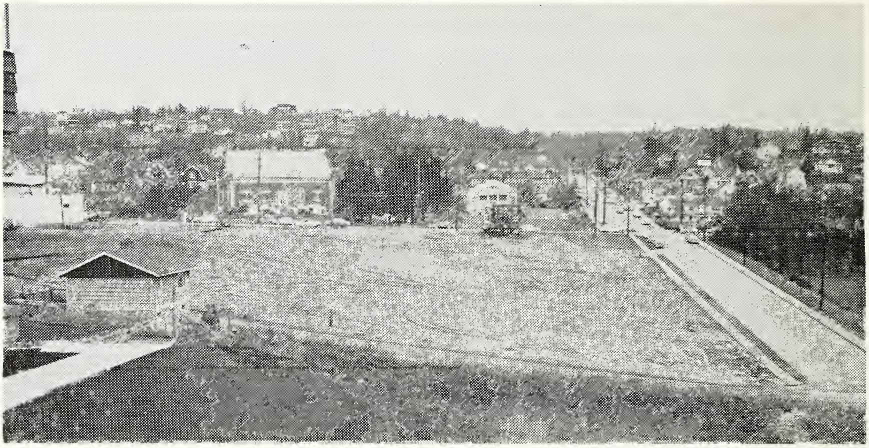


Fig. 38. A well operated landfill can be located in the center of a good residential and commercial area without complaints from neighbors; and this site, one of many in Seattle, does not require a long haul for collection trucks. The level area was an unsightly hole before it was filled.

be improved usually overcomes these objections.

In any event, if the refuse to be disposed of in a fill contains garbage, the site should not be closer than one-quarter of a mile to residential, institutional, or industrial buildings, unless unusual circumstances make a closer location both desirable and acceptable.

Accessibility

The site should have several access roads so that if one road is temporarily unusable, the site is not isolated. One small town selected a disposal site two miles away on the opposite side of a river that practically always flooded for a week or two in the spring. When the river was at flood, a round-about, 10-mile haul over almost impassable gravel roads was required.

In metropolitan areas access roads that permit trucks to be routed away from residential, commercial, and industrial sections are desirable.

Length of Hauls

The question of whether to use the sanitary landfill method of disposal or another method, such as incineration, is frequently influenced by the costs of hauling. The question is, how far is too far for a haul? Only an engineering analysis can give the answer. For example, it may be more economical to haul refuse a long distance in a 20-cubic-yard compactor-type truck that makes only one trip a day than to haul it a shorter distance in equipment that must make two, three, or more trips. The use of large-volume vehicles for long hauls from close-in transfer stations may increase the distance it is economical to haul refuse by as much as 25 to 50 miles.

The cost of labor and transfer stations must be computed in costs, however. A report of a University of California sanitary engineering research project tells how such analyses can be made.[2]

In some cases long hauls are compensated for because trucks can go faster on lightly traveled open streets to outlying sites. Dallas and Fort Worth, Texas, have used "rim" sites just outside city limits that can be reached quickly.

Climatology

Weather is a significant factor in evaluating landfill sites in some areas of the country. Extremely cold weather can prevent excavation for cover, making it necessary to excavate and stockpile it during warm weather. A prolonged rainy spell can flood low areas, making it difficult for refuse vehicles to maneuver at the fill. The intensity and direction of prevailing winds are also important in controlling blowing paper and in determining in which direction odors will be blown.

Local climate conditions may eliminate some sites, require unusual techniques of operation at others, or rule out landfills as the disposal method entirely under extreme conditions.

Drainage

Proper drainage for the fill itself is important, but it is also important to consider what effect the fill will have on natural drainage in the area. For example, filling a ravine that is dry most of the year but which is the channel for a roaring torrent of water after a cloudburst will make the fill an unsatisfactory one and eliminate a necessary channel for storm waters. Normal heavy runoff usually can be inexpensively diverted around the fill area, however. Nor should landfill operations in low areas be planned so that refuse cells become dams that prevent runoff from escaping.

Future Land Uses

The improvement of property by filling it is one of the chief economic advantages of the sanitary landfill method of disposal. Many cities have turned mosquito producing pestholes into play areas, athletic fields, and parks. Others have used completed sanitary fills to extend airport runways or as sites for industrial buildings. A city must consider how it can use a landfill site when it is completed.

To answer this question satisfactorily it is necessary to consider physical and biochemical reactions of the mass of compacted and covered refuse and the impact of operational practices on it. Construction of houses on sanitary fills is usually discouraged, and heavy construction should be permitted only after careful engineering studies.

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[2] University of California, Sanitary Engineering Research Project, *An Analysis of Refuse Collection and Sanitary Landfill Disposal* (Richmond: 1952). Technical Bulletin No. 8, 133 pp.

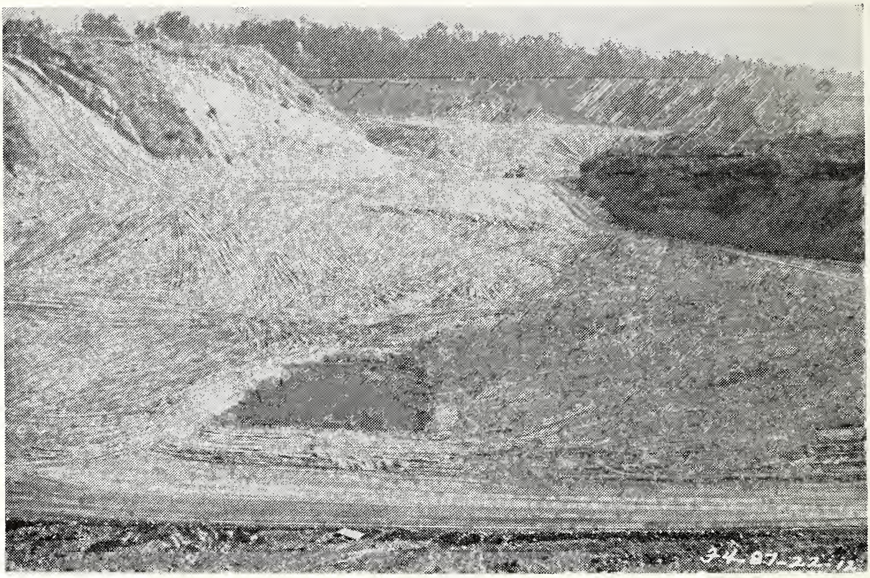


Fig. 39. There is little indication at the close of each day that this is a landfill site. Covering the site with earth material each night also helps control fires, odors, and insects and rodents.

Costs

Costs of fills vary widely, even within a city. The cost of the site, site preparation, and operating costs must all be computed to determine which site is economically best. (In Los Angeles, excavations for landfills have cost in excess of $1 million.) The initial cost, however, must be balanced off against the value of the land when the fill is completed. Often the land increases in value appreciably.

Zoning Regulations

A survey conducted by the APWA in 1956 showed that a high percentage of cities in the United States are restricted in the acquisition of disposal sites by their zoning ordinances. Of 742 cities reporting, 436, or almost 60 per cent, said they were so restricted. The Michigan Supreme Court, however, has ruled that a sanitary landfill is not an ultimate land use and therefore cannot be prohibited on the basis of zoning laws.

Public Acceptance

The importance of public acceptance of a site for a sanitary landfill cannot be overemphasized. Even though a proposed site is in an uninhabitated area, the people who regularly drive past it may think it will be undesirable and protest having it there, sometimes successfully. Some cities—Seattle, Washington, for example—consider that public approval of a landfill site is the most important factor in deciding on its use.

Site Preparation

Site preparation is the readying of an area for sanitary landfill operations. How well it is done spells the difference between success and failure in the operation.

The extent of the preparations for a particular site depends on the nature and location of the site, the size of the operation, and, of course, the amount of money available.

The following steps should be taken or facilities provided for most sites, although not all are necessary for every fill:

1. Make an engineering survey to permit accurate planning for access roads, drainage, lift heights, diversion channels, dikes or levees; to determine soil characteristics; and to estimate the life of the site.
2. Build a semipermanent, all-weather road on the site and a vehicle turn-around if needed.
3. Build an all-weather access road to the site.
4. Take measures to prevent paper from being wind-blown.
5. Build appurtenances for aesthetic reasons, such as an earth berm or solid fence around the site to screen the activity.
6. Provide suitable facilities for storing and servicing equipment.
7. Provide facilities for workmen.
8. Install scales to weigh refuse to help determine costs and to improve management practices.
9. Provide utilities–electricity, telephones, water for fire fighting.
10. Do site work: clear trees, divert springs or brooks, and remove and store top soil for cover material or procure other cover material.

Engineering Survey

To be successful and economical, a sanitary fill should be handled like any other engineering project. Planning should include studies, drawings, and specifications. The survey should result in basic data from which recommendations can be made for construction of access roads, depth of fill, plan of operation, location and amount of stockpiled earth cover material required, grades for proper drainage, and the probable life expectancy of the site for landfill purposes. The planned or potential use of the site must also be considered.

As a first step, a detailed topographic site survey (at a scale of not more than 200 feet to the inch with 2-foot contour intervals for the average level site) is recommended.

Amount of Land Required. The amount of land required for a fill and the length of time it can be used for disposal can be estimated fairly accurately on the basis of data on refuse production, compaction, density, and the amount of settling that can be anticipated in fill sites. The following pointers can be used in making calculations:

1. The compaction ratio (volume of refuse received to the volume after compaction) varies from 1:1 to 3:1, depending on the type of refuse, amount of precompaction in collection vehicles, field com-

paction procedures, depth of fill, number of layers, and compactability of underlying earth.

2. Analysis of APWA data from 42 cities using sanitary landfills showed that the weight of refuse collected and delivered to fills varied from 0.14 to 1.67 tons per capita per year. The median was 0.53 tons per capita per year (2.9 pounds per capita per calendar day). Data on volume reported by 66 cities showed a range of from 0.25 to 10 cubic yards per capita per year, averaging 2.26 cubic yards per capita per year. The median was two cubic yards.
3. The average density of mixed refuse, if collected in compaction-type vehicles, is about 300 to 400 pounds per cubic yard when delivered to a fill. If the amount of ashes in the refuse is negligible, the density is approximately 300 to 350 pounds per cubic yard.
4. Allowance should be made for volume of earth cover. (Intermediate covers, if fill is made in more than one layer, are usually a maximum of 12 inches thick on top, sides, and face. The final cover should be at least 24 inches thick.)

The volume of refuse required for sanitary landfills differs markedly from one city to another because of local conditions. One city may handle only residential refuse at its sanitary landfill, for example, and commercial refuse may be disposed of differently. Another city may dispose of all normal solid wastes in sanitary landfills.

Volume requirements may be calculated as follows:

$$V = \frac{R}{D}\left(1 - \frac{P}{100}\right) + C_v$$

V = volume required for refuse disposed of per capita per year in cubic yards

R = amount of refuse in pounds per capita per year to be handled at landfill

D = average density of refuse in pounds per cubic yard

P = per cent reduction of refuse from compaction

C_v = volume of cover material required in cubic yards (6 to 12 inches on intermediate layers, temporary sides, front slopes, and top; at least 24 inches on finished surfaces.

Experience shows that C_v will approximate from 17 per cent for deep fills to 33 per cent for shallow fills. An average of 25 per cent is sound. Accordingly, the formula becomes:

$$V = 1.25\,\frac{R}{D}\left(1 - \frac{P}{100}\right).$$

An example: commercial and residential refuse from a city of 20,000 is to be disposed of at a landfill using nine-foot levels (including earth cover); the community uses primarily natural gas for domestic heating, thus making the ash content of the refuse negligible. The average amount of refuse for the city in one year is calculated thus:

$$V = \frac{1.25 \times 2.9 \times 365}{325}\left(1 - \frac{50}{100}\right) \quad \text{and}$$

V = 2.03 cubic yards per capita per year, where
R = 2.9 pounds per capita per calendar day
D = 325 pounds per cubic yard
P = 50 per cent (assuming average reduction ratio of 1:2).

Therefore, the number of acres of land required each year is computed thus:

$$A = \frac{2.03 \times 27}{9} \times \frac{1}{43{,}560} \times 20{,}000 = 3.02 \text{ acres}$$

(which is approximately 1.5 acres per year per 10,000 population for a 9-foot compacted depth, including 25 per cent cover.

Site Investigations. Site investigations vary according to circumstances. When Mandan, North Dakota, for instance, a city of 7,000, started sanitary landfill operations, engineering investigations included several test borings of a proposed site to confirm that it had satisfactory earth cover available in sufficient quantities; preparation of a topographic map of the site (Figure 40) and plans and drawings for an access road to the site from a county road.

In New York City, on the other hand, an engineering study for a sanitary landfill in a lagoon included data on demolition of condemned structures near the site; data on sand for cover material by hydraulic dredging; information on construction of tidegates and dikes and on extension of water, electric and telephone lines; installation of truck weighing scales; and on construction of a building for equipment and facilities for employees.

The amount and type of earth cover material available should be determined by on-site tests. Ordinarily the tests consist of borings to the depth contemplated for removal of cover material. As many borings as are necessary to get a true picture of soil conditions should be taken. For sites of only a few acres and in which the geological formations are known, only a few confirmatory borings need be made. For large sites on which little geological data are available, a dozen or more borings may be required. Similar investigations may be required of any off-site sources of cover material.

Access Roads

Access roads to a site should be so constructed that traffic is not interrupted by inclement weather or climatological conditions such as spring thaws and "rainy seasons." They should be at least 22 feet wide and have a minimum curve radius of 75 feet if use of large transfer vehicles is anticipated. There often is a road meeting specifications adjacent to small fill sites—perhaps a well-drained, graded, gravel road. Depending on the amount of truck traffic and the proximity of the road to dwellings, it may be necessary to control dust by sprinkling with water or treating with calcium chloride, oil, or penetration macadam. Soil cement techniques or a seal coat of penetration asphalt topped with aggregate are often used in contruction of such roads.

On large fill sites, such as those in New York City, a semipermanent,

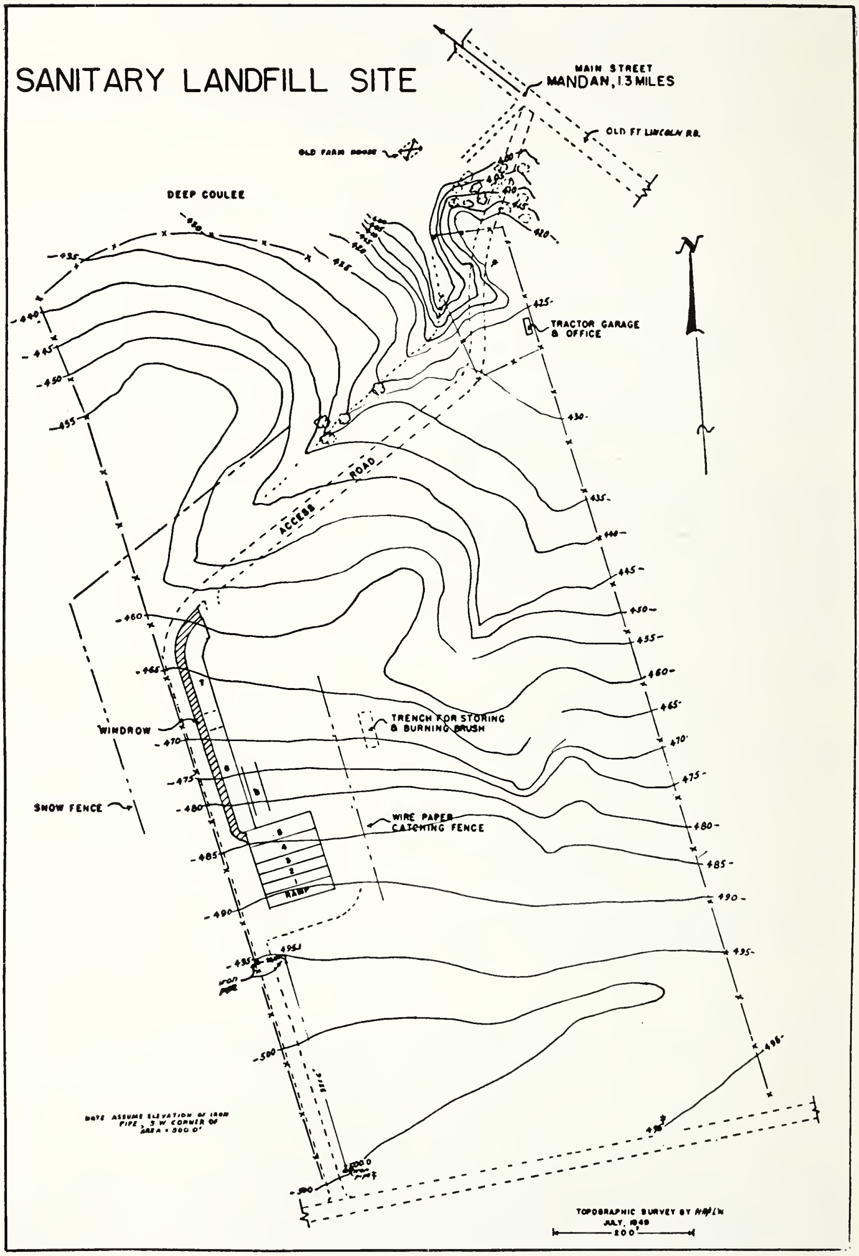

SANITARY LANDFILL SITE
MAIN STREET
MANDAN, 1.3 MILES
OLD FT LINCOLN RD.
OLD FARM HOUSE
DEEP COULEE
TRACTOR GARAGE & OFFICE
N
ACCESS ROAD
TRENCH FOR STORING & BURNING BRUSH
WINDROW
SNOW FENCE
WIRE PAPER CATCHING FENCE
RAMP
IRON PIPE
NOTE ASSUME ELEVATION OF IRON PIPE, S W CORNER OF AREA = 500.0'
500.0 IRON PIPE
TOPOGRAPHIC SURVEY BY H&L W
JULY, 1949
200'
435
440
445
450
455
460
465
470
475
480
485
490
495
500
430
425
420
415
410
405
400

Fig. 40. An engineering survey should be made and a topographic map prepared before landfill operations are started. This map was made of a landfill site in Mandan, North Dakota.

hard surfaced road is built from the point of entry of the site to the dumping point. An all-weather road, extended periodically as work progresses along the face of the fill, will speed up operations and, more important, will pay for itself several times over by reducing damage to trucks.

Overhead lights should be installed along the access road and near the bank of the fill for night operations. Portable generators at the bank of the fill may suffice. Access roads should be kept clear of papers and rubbish, which are fire hazards and are objectionable; and should also be kept clear of glass, scrap metal fragments, and other materials that cut tires.

Fencing

Fences at sanitary landfill sites serve three purposes: (1) cut off the view of the operation for neighbors and passersby; (2) control entry to the site; and (3) control wind-blown paper.

In New York City the view of a fill operation is cut off by an earth berm 8 to 10 feet high, which is topped by an 8-foot wire fence with burlap covering if it is necessary to confine wind-blown debris and dust. Snow fences to catch blowing papers are also sometimes put up temporarily in the immediate vicinity of the dumping operation.

No special effort is made to conceal landfill operations in most cities, however. If sight of the operations is a point of contention for the public, the problem can usually be solved by selecting a relatively isolated site.

Many methods have been devised to prevent wind-blown paper from becoming a nuisance and fire hazard. Use of snow fence in the immediate operating area (about 50 to 75 feet downwind from the operating face of the fill) has been found to be effective and is popular because it is readily available, is relatively inexpensive, and is easily set up and moved as required. In some places, however, snow fences are not permitted because paper cannot be burned off the wood slats.

Metal fencing is often used to catch paper, especially if the fence encloses the entire disposal area. Hogwire type fencing is generally recommended. It is strong and may be obtained in varying heights. Wire fencing with less strength is not recommended because a strong wind can cause abnormally high pressure on the fence if a lot of paper is "plastered" against it. Portable sectional fencing mounted on skids has been used on sanitary landfills. As the operational area changes, the fence may be pulled by a tractor to a new location.

Fences, it should be realized, are often used to solve a problem that could have been avoided in the first place by selection of a more sheltered site and use of recommended truck unloading procedures. A fill site on a windy plain, for example, presents a much more difficult problem than a site in a valley. One city had to solve the problems caused by a poor site by excavating 12-foot trenches and erecting an earth berm perpendicular to the axis of the prevailing wind as a wind block. All trucks were unloaded in the trench itself on especially windy days.

Fences that help prevent access to a fill by unauthorized vehicles and dumping after hours can be of any of a number of materials and styles, depending on local considerations.

Facilities for Personnel and Equipment

What kinds and how many facilities should be provided on the site for workers and equipment are governed by location and size of each landfill. In the arid southwest states a carport-type structure may suffice as a garage for a tractor, whereas in the northern states a well-insulated heated garage may be needed.

Sanitary facilities for site personnel are desirable even at the smallest site. Arrangements may be made with a nearby business establishment, or at large operations a portable privy may be installed on the site.

Semiportable sheds should be located near the main entrance to large landfill sites for use as operation headquarters and as a base for employees. The sheds should be heated if necessary, have water and sewage facilities, and when feasible, lights, lockers, showers, and telephones.

Weighing Facilities

Accurate data on quantities of refuse are desirable for cost accounting purposes and as an aid to good management. If the data are to be used for comparison they must be reasonably accurate. Experience shows that the only accurate data for comparison purposes are based on weight—not volume. Few cities in the United States have weighing facilities on landfill sites, however, probably because many city officials do not understand the need for them, making it difficult to justify the cost.

Cities that charge private haulers for depositing refuse in a fill frequently have scales because they charge on the basis of weight. The New York Department of Sanitation uses semiportable weighing rooms with truck scales in the area adjoining the sheds for equipment and employees. Devices that automatically figure charges for disposal on the basis of the weight of the refuse are used by the New York City and the Los Angeles County sanitation departments.

Portable scales may be adequate on temporary disposal sites or arrangements sometimes can be made with a local businessman to rent a scale.

Cover Material

A suitable inert, granular material must be used to cover compacted refuse at the working face and top surfaces of a landfill project. Cover material prevents refuse from blowing and being scattered, helps control odors, helps prevent invasion of the fill by rodents and insects, and lessens fire hazards by sealing "cells" of refuse, thus precluding the spread of internal fires that may occur. A compacted cover also makes the fill firmer and easier for vehicles to drive over.

The most desirable type of earth cover material for a fill is classified by the United States Bureau of Public Roads as "sandy loam." Clean earth or its equivalent should be used and it should be relatively free of organic matter, tree roots, branches, stones more than six inches in diameter, bulky building materials, and have a low clay content. Soil that has a low clay content can help prevent quagmires, prevent equipment from bogging down in wet weather, and minimize the formation of cracks in the fill cover. The cracks provide access for rodents and insects to the buried refuse and may permit odorous gases to escape from the fill. Many large stones in the cover material cause similar difficulties. The proper cover material assures good traction for vehicles in all weather, safeguards against unequal settlement and against heaving action of the fill, and reduces surface cracking. Clean ashes or incinerator residue are adequate for intermediate working cover.

The quantity of cover material is customarily expressed as the ratio of the volume of cover material to the volume of compacted refuse. For example, a 1:4 cover ratio indicates that 20 per cent of the compacted volume of a landfill consists of cover material. The cover ratio required for results consistent with good engineering practices varies with the type and location of the landfill and the proposed use of the completed site. The most important consideration—public health—requires that at least a six-inch compacted layer of cover material be put on the top surface of each lift as it is constructed and, in addition, that all exposed refuse be covered at the end of each working period, usually once each day but more frequently if necessary.

The Los Angeles County engineer has determined that a cover ratio of 1:4, or 20 per cent, is satisfactory for the Los Angeles area, and it is required at all landfill sites operating under permits issued by the county engineer. In Burbank, California, a cover ratio of about 1:3 has been found to be satisfactory for a landfill that, because of its proximity to a residential area, must have all surfaces of the refuse covered daily. In very large fills, however, such as those in New York, where compacted depths go up to 40 feet (made in two to four lifts), the cover ratio is substantially less.

The costs of procuring suitable cover on a site by private contract will range from about 30 cents to $1 a cubic yard, depending on local conditions.

Cover material is usually spread by bulldozer, bullclam, or carryall in a uniform layer over previously compacted refuse. The process of continuous mixing of cover material and refuse for optimum compaction has several disadvantages that make it impractical for large-scale operations and is, therefore, not recommended. Continuous mixing of cover and refuse is difficult with the usual landfill equipment and materially increases costs. Surface layers of compacted cover are required in addition to the continuously mixed cover, thereby increasing the amount of cover material required.

On the other hand, a continuous mix landfill may have less voids than one with conventional cell structure, thus slightly increasing the refuse capacity and minimizing settlement. There may be cases in which the increased cost of the continuous mixing process is justified, although by 1960 there were no landfills known to be using a true continuous mixing process.

Compactibility of soil depends primarily on the gradient of particle size; that is, soil with a homogeneous particle size does not compact as well as soil containing particles with a wide range of sizes. Nearly pure sands, clays, and silts are not suitable for cover material on sanitary landfills unless especially treated. For example, calcium sulfate has been applied at the rate of 20 pounds per acre for aggregation of silts used as cover on Bergen County, New Jersey, landfills. The final layer of cover is disk harrowed and seeded with rye grass. Crushed rock with no soil binder is likewise unsuitable for fill cover.

New York City has developed a process of converting sand obtained by dredging into cover material by inundating (ponding) the surface of the sand with digested sewage sludge (about 95 per cent liquid). After a drying out period, the sand and sludge are thoroughly mixed by mechanical plowing. The result is excellent cover soil obtained much more economically than if material had been imported.

Landfills in Dry Areas

When sanitary landfills were first used for refuse disposal in the United States, it was convenient to classify the methods of operation as the area method and the trench method. As techniques changed over the years on the basis of experience, the two classifications became inadequate. New names for new methods were thought up and used.

Of the types of landfills in dry areas, two are now common: area landfills—on essentially flat land sites; and depression landfills—on sites that use natural or man-made depressions or irregularities in the terrain, such as canyons, ravines, and pits.

Area Landfills

One of three methods of operation is usually used for area landfills—progressive excavation, cut and cover, or imported cover.

Progressive Excavation. The distinguishing feature of the progressive excavation method is its continuity. Cover material is excavated from the area directly in front of the working face of the landfill and is put over the previously compacted refuse behind. The cover is excavated as required and the process goes on almost continuously.

Progressive excavation landfills are usually operated with bullclams or bulldozers and have a ramp-type working face, as shown in Figure 41. Scrapers may also be used on larger operations. It is possible, however, to operate a trench-type or cut and cover progressive excavation landfill with dragline or carryall. This has been done in Fresno, where a dragline operates next to an excavated trench in front of and moving parallel to the plane of the working face while compacting and covering the refuse in a continuous operation.

The original ramp or trench for dumping of cells of refuse may be

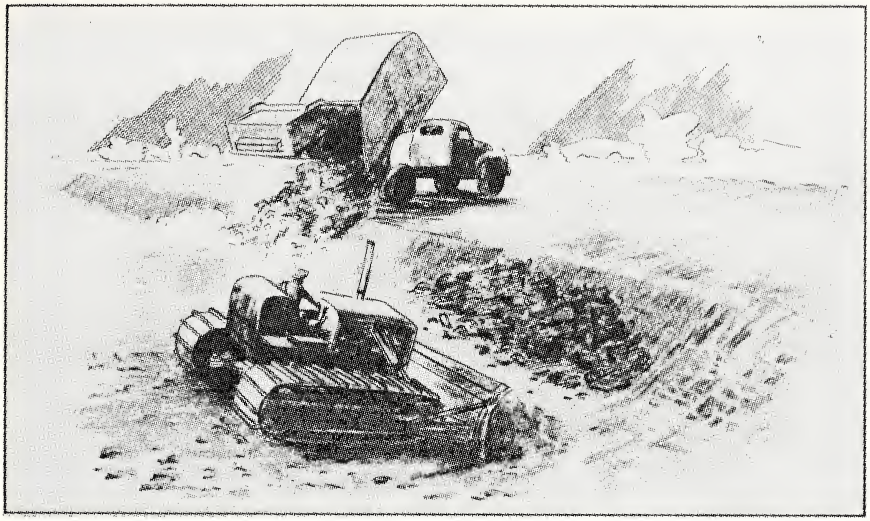


Fig. 41. In an area-type landfill, refuse is discharged on or adjacent to the working face of the fill and a bulldozer places and compacts the refuse and covers it. A progressive excavation project utilizing earth adjacent to the working face for cover material is illustrated.

prepared in any convenient way. If there is a natural bank or other suitable terrain feature on a site, advantage should be taken of it. A bulldozer can easily prepare an earth ramp or cover a windrow of compacted refuse and thus fashion a ramp. Any such scheme is satisfactory.

The point at which refuse is discharged on the working face of the fill has a direct influence on the ease with which refuse is spread and compacted. It has been found by bulldozer operators working ramp-type fills in San Diego and Los Angeles County that it is easier to see the work and to control spreading if refuse is discharged at the base of the working face and spread from the bottom up. Dumping at the bottom of the face has been found to result also in better compaction because collection vehicles drive over it when it is completed to reach the working area. Discharging refuse at the base of the working face also sometimes hides the disposal operation from the public view and minimizes the amount of paper blown about—important factors at fills near residential areas.

Discharging refuse at the top of the working face requires that loaded collection trucks climb to the top of the fill. Top dumping should be avoided particularly on fills higher than 10 feet because refuse is scattered over a wider area than with bottom dumping. It may be necessary to do so, however, when roads are muddy or for some other reason are impassable.

A 35,000-pound crawler tractor with a dozer blade can dispose of 250 to 300 tons of refuse in each eight-hour working day by this method, assuming that excavation of cover presents no difficulties and requires no extra equipment. Equipment capacities are discussed in more detail later.

Cut and Cover. A cut and cover fill is one in which trench-type excavations are made on the site to hold the refuse and get cover material. The trenches are usually parallel to each other in order to use the site efficiently. The excavated earth, usually stockpiled adjacent to the excavation, becomes the cover material.

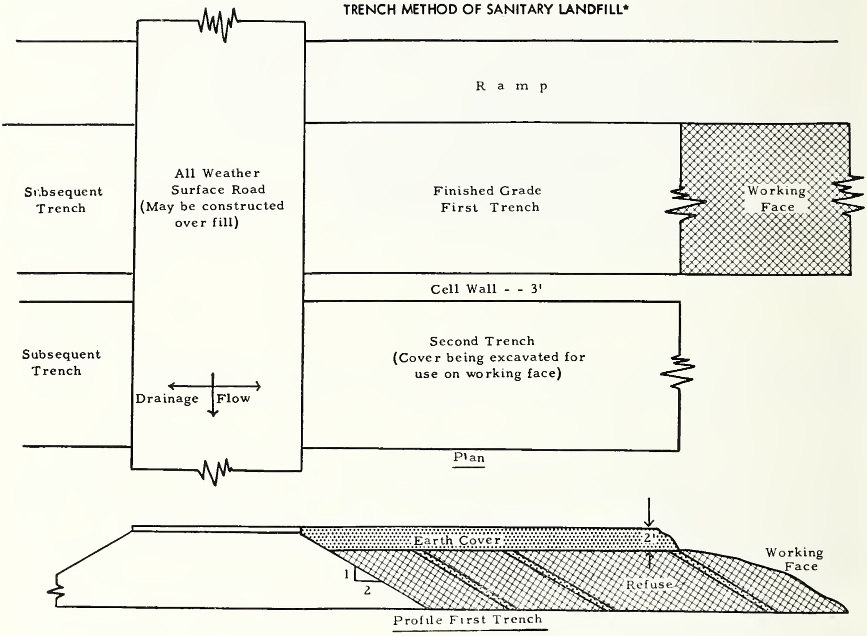

TRENCH METHOD OF SANITARY LANDFILL*
Ramp
Subsequent Trench
All Weather Surface Road (May be constructed over fill)
Finished Grade First Trench
Working Face
Cell Wall - - 3'
Subsequent Trench
Second Trench (Cover being excavated for use on working face)
Drainage Flow
Plan
Earth Cover
2'
1
2
Refuse
Working Face
Profile First Trench

Fig. 42. In the area landfill known as the cut and cover or trench type, earth cover material is obtained on the site either by excavating the trench ahead of the working face or by excavating a trench that is to be filled later. Plans for this fill call for getting cover material from a subsequent trench.

With the cut and cover process, the amount of earth excavated may exceed the cover requirements. Such was the case at a Torrance, California, municipal landfill, where excess earth was sold as borrow material, providing additional disposal space at the landfill.

The rate of excavation in a cut and cover fill may bear no relation to the rate of disposal. In fact, the most popular practice is to excavate enough trenches at one time to provide space for disposal for a long time. In the northern part of the United States it is customary to excavate enough trenches and stockpile enough cover material to last throughout the freezing weather. It may also be advantageous to excavate ahead in areas where periods of heavy rainfall can be anticipated.

Unlike the progressive excavation method, refuse at a cut and cover fill is usually discharged at the top of the working face, although in some cases it may be desirable to discharge it at the bottom. Spreading and compaction of the refuse is usually done by bulldozer, as it was at the Mission Bay site in San Diego, California.

The cut and cover method is well suited to sites on which excavations are made below ground water level, which is common at tideland and mud flat sites. A dragline is essential for excavating on such operations.

Imported Cover. The imported cover method of operating a landfill is not a single method but rather several, and is used when cover material is obtained from a source outside the site. Refuse is dumped and compacted with bulldozer, bullclam, or dragline as it is in other methods of area fill. The volume of refuse that can be disposed of at an imported cover site is about 20 per cent less than it is at a site at which the cover material is excavated.

The imported cover method is used for one of two reasons: (1) if there is excess borrow at a nearby excavation that makes it convenient and economical to use the borrow as cover for the fill; (2) if suitable material is not available on the landfill site, such as rock quarry pits or area fills on which one lift has been completed.

Traffic is sometimes a major problem at landfills using imported cover, particularly if the refuse is discharged mostly from collection vehicles rather than from transfer vehicles and if cover is not stockpiled but delivered frequently. In Seattle it was found that traffic congestion at the site caused by refuse collection vehicles and vehicles delivering cover can be reduced by having refuse trucks dump at the bottom of the lift and the cover delivery trucks at the top. Trucks hauling cover material should be routed over roads that create a minimum of dust and noise and over highways that can stand the weight of the loaded trucks.

Although cover material can be delivered as needed, it is good practice to stockpile it against vehicle failure or work stoppages at the source.

Depression Landfills

Depression fills are those that use natural or man-made irregularities or depressions in topography. The methods of operating all depression fills are so nearly alike that it is convenient to categorize the fills according to dominant physical features rather than methods of operation. Depression fills are classified as either canyon and ravine or pit and quarry.

Usually the total depth of the refuse in a depression site is greater than the depth in an area fill. The fill is constructed by dumping refuse in sloping layers and compacting it. Each stratum thus formed has a total depth of from 4 to 20 feet. Each layer must be well covered with compacted, inert cover material; and it is good practice to cover the sloped working face at the end of each work period.

Canyons and Ravines. (Although only "canyons" are mentioned from here on, similar methods are used for ravines.) The two principal criteria

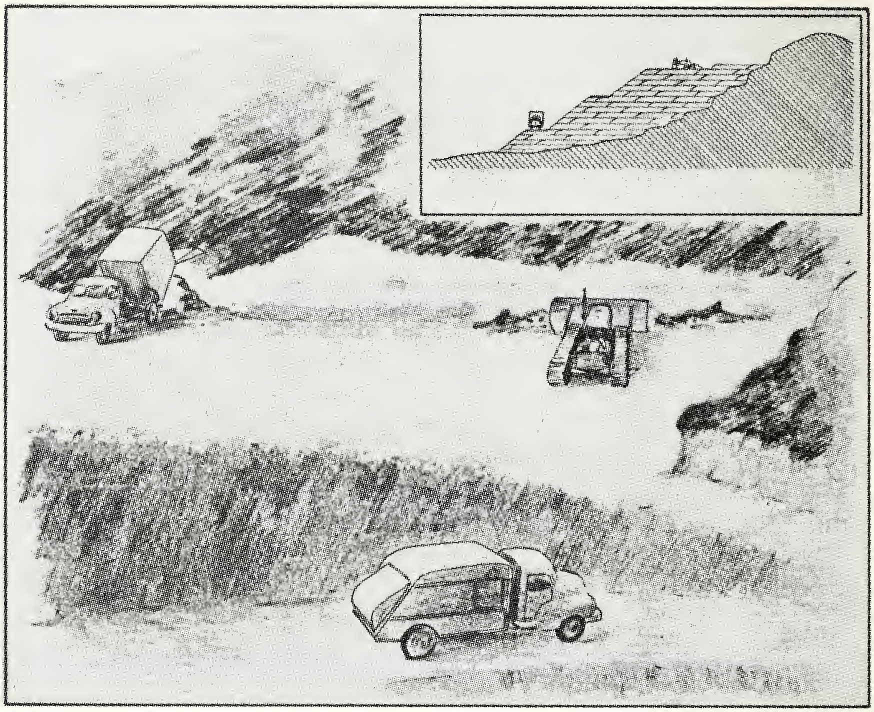


Fig. 43. In the canyon landfill, refuse is placed in the same way that it is in an area landfill; cover material is excavated from canyon walls. The inset shows a cross section of a typical canyon fill in the Los Angeles basin, with access roads built up the sloping face of the fill.

for determining the acceptability of a canyon as a site for a fill are physical configuration and soil type. A relatively flat bottom grade is desirable because it makes it easier for vehicles to go in and out of the canyon. Since all cover material except that for the first stratum is excavated from the canyon sides, it is advantageous if the canyon is long and narrow and has a flat bottom. The type of soil available for cover determines the type of equipment needed for excavating, hauling, spreading, and compacting.

The stability of exposed fill slopes must be considered. Experience indicates that slopes of 2:1 are acceptable and only those approaching 1:1 need be subjected to rigorous analysis. No known attempt has been made to determine shear values or sliding resistance for in-place refuse fill.

The interface between refuse fill and native terrain may be a plane of low shear. If this interface is close to the sliding circle of the fill and reliable shear values cannot be determined, it may prove good practice to terrace the native terrain before dumping refuse.

Usually each lift of a canyon landfill is begun at the head of the canyon and ended at the mouth, which prevents water from ponding in back of the fill and makes it easier for disposal trucks. The first lift of a canyon fill may be carried out by the progressive excavation method if the canyon floor is essentially flat and of reasonable size.

Refuse is usually dumped at the base of the working face of a canyon fill so that refuse trucks do not have to go to the top, and because there is better control and compaction if the refuse is worked from the bottom to the top of the slope rather than from the top down.

The distance between the source of cover material and the working face varies during the operation. Cover material that is 300 to 400 feet away from the face of the fill can be moved most economically by a bulldozer or crawler-tractor with shovel attachment. If cover must be moved more than 500 feet, a carryall scraper is more economical for the job, and it can be used to spread cover over the top of the lift or the working face uniformly and efficiently as it unloads. If cover must be moved 1,000 feet or more over an extended period of time, the suitability of various types of haul equipment should be studied and evaluated. For example, a rubber-tired tractor pulling a rubber-tired scraper loaded with the help of crawler-tractor "pusher" might be the most economical equipment.

The nature of the cover material determines the kind of equipment required for excavation and can significantly affect the cost of operating a landfill. Loose sand and loam mixtures, loose sand and clay mixtures, soft decomposed granite, and well-fractured or loosely-cemented sedimentary deposits can be excavated easily with a bulldozer or carryall scraper. Clay, adobe, well-compacted sand and clay mixtures, well-cemented sedimentary deposits, partially decomposed granite, and the like often require loosening with a ripper before bulldozer or carryall excavation.

Canyons with geological structures consisting of well-consolidated sedimentary deposits or poorly fractured and poorly weathered igneous or metamorphic formations of solid rock should be avoided if there is a satisfactory alternate site, because blasting may be required before excavation with a bulldozer or carryall scraper. Material that requires blasting is usually poorly suited for cover, and blasting is discouraged near heavily populated areas. At remote sites, blasting may be feasible and prove to be a more economical method of loosening well-compacted material than ripping. Soil borings should be made before a canyon is selected as a landfill site; and to avoid importing cover material, it must be determined that there is sufficient suitable material at the site. A workable criterion is that the cross sectional area of available cover material at the section of any stratum or lift should be at least 25 per cent of the total cross sectional area of the canyon at that stratum.

Rain water runoff concentrates in canyon sites; consequently, it is important that there be adequate drainage. If the boundary of a canyon site does not include an entire watershed, adequate drainage must be provided for the watershed area above the landfill. In many cases, a diversion ditch may be dug just above the expected final grade of the fill to divert runoff water from that part of the canyon or watershed above the site. This has been done successfully at the Arizona Fill, operated by the city of San Diego. It may prove more economical in some cases to lay a culvert along the centerline of the canyon and thus provide drainage under the fill rather than around the sides or over the top of it. Drainage for the surface of the fill itself must also be provided. The top of a canyon fill may be crowned and drained by a 1 or 2 per cent grade to the sides of the fill or may be drained to the center and face with a 1 or 2 per cent grade. The latter may be preferred because it reduces the shear angle (due to moisture) at the contact surfaces of canyon sides.

Surface runoff concentrated at the edges or center of a fill surface must be carried away in such a manner that the fill face does not erode. A drainage ditch along the access road may be suitable, but if the fill face is not traversed by an access road, it must have transverse drainage ditches adequate to prevent erosion by surface runoff. Finished fill faces should be planted with cover crops suitable for surface erosion control. Mustard and wild rye have been found acceptable.

Access roads into canyon sites cannot have a steeper grade than fully loaded refuse collection trucks can climb—a maximum grade of about 15 per cent for an average refuse truck. Every effort should be made to minimize access road grades. If access roads are on the slopes of the canyon that are adjacent to the site, the roads will not take up part of the site that can be filled. An access road on the face of canyon landfills not only reduces the space that can be filled but also requires special care in building.

Dry Pits and Quarries. Pit and quarry landfill sites are lower at all points than the surrounding terrain and consequently are not drained by surface channels; as with canyon sites, pit sites are usually so deep that they must be filled by several lifts or strata of refuse.

Pit and quarry sites are operated in essentially the same way as canyon sites. Refuse is transported to the working face via an access road that should be built on the same principles as canyon site access roads. Refuse is discharged adjacent to the working face, either at the bottom or the top of the lift. Discharging at the top makes the dumping and travel easier and faster for the trucks. If careful control is to be maintained and high densities are to be achieved, however, it is recommended that the fill be constructed of lifts built by bulldozing and compacting refuse from the bottom of the working face up in sloping layers, as shown in Figure 44.

It is important that a pit or quarry site have enough excavatable material around its periphery to cover the entire capacity of the fill. In most cases this will require a volume of cover equal to at least 25 per cent of the original volume of the pit. In most pits it is economical to operate the first lift of the fill by the progressive excavation method, avoiding transportation of cover material from the periphery of the pit, which is necessary with subsequent lifts. If the pit is very large in area, requiring long cover hauls, or if the amount of cover material is in-

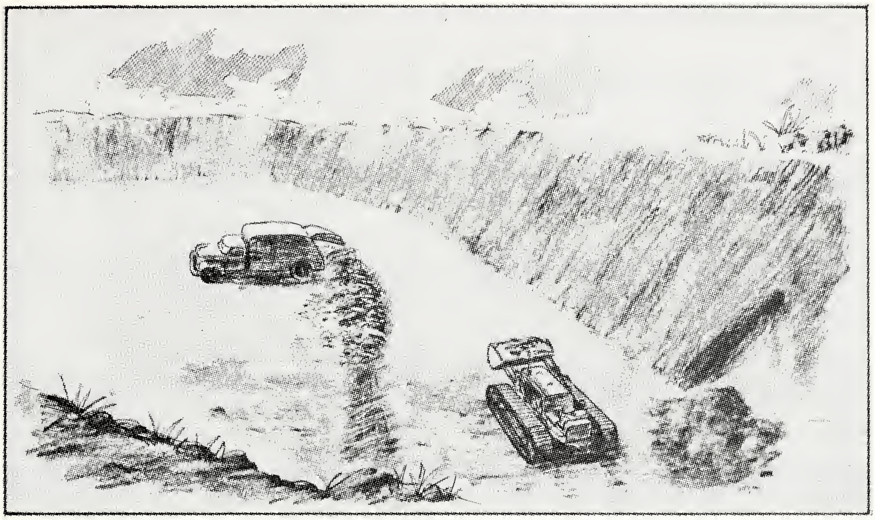


Fig. 44. In the pit and quarry type landfill, refuse is placed and compacted in horizontal layers, or "lifts," and covered with material excavated from the sides of the pit or brought in from borrow areas. If a pit fill is large, it is necessary to use carryalls to economically transport cover material.

adequate, it is advisable to consider stockpiling cover material from the pit bottom. The quantity of cover to be stockpiled should be carefully calculated before the fill is begun. If it is impossible to obtain sufficient cover material at the site, a decision to use the pit as an imported cover landfill should be based on a careful economic analysis, as importation of cover material may be prohibitively expensive.

It is desirable that a pit or quarry site be filled to a level slightly above the grade of the surrounding terrain to allow for long-range settling and to obviate problems of surface runoff.

Landfills in Wet Areas

Wet sites for landfills are of three general types: swamps and marshes; tidal areas with fluctuating water depths; and ponds, quarries, and similar depressions that have standing water in them.

A general plan of the long-range development of the site should be drawn up before operations are started. The plan should include information on the final grades and depths of fill, the drainage system, the amount of cover material required, potential volume of the fill, and its life expectancy. If over-all city plans call for highways, bridges, buildings for heavy industry, or other major improvements to be built in the area, it may be necessary to avoid using the area for landfills. Sewers, storm drains, and other large conduits that are to be built in the area of a site probably should be completed before the landfill operation is started.

Swamps and Marshes

For landfills in swamps or marshes it is of utmost importance to construct and maintain a drainage system adequate to handle both ground water runoff from adjoining uplands and surface runoff from newly filled plateaus. The discharge end of the drainage ditches should be equipped with readily cleanable trash screens. If discharge is into tidal waters, the course screen should be supplemented with flap gates to control backflows.

Filling strips should be extended from a previously constructed operating platform. This platform, built up from either compacted refuse or other readily available material to about 5 feet above marsh elevation, facilitates maneuvering of trucks and makes operations more flexible.

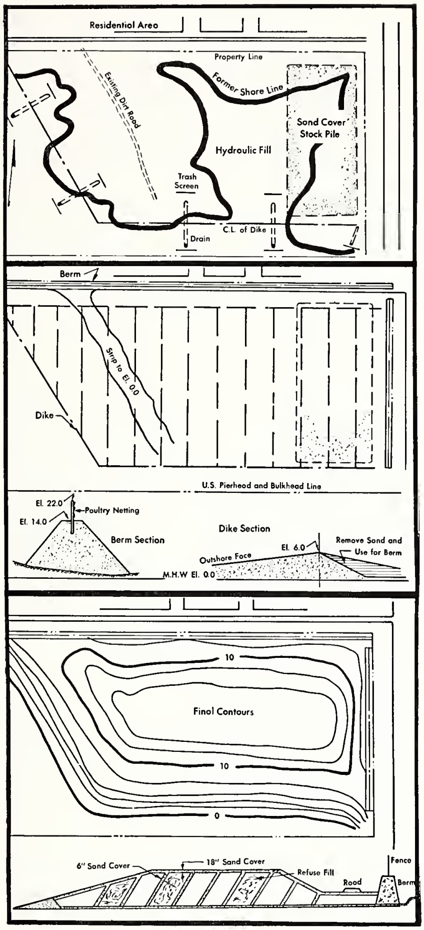
Filling operations should be scheduled and controlled so as to preclude, or at least alleviate, mud waves, which may cause structural problems, interfere with normal drainage, and create odor and insect nuisances by stirring up organic silt. The schedule can be carried out by constructing a lagoon with fingers of refuse as described in the following section on tidal areas.

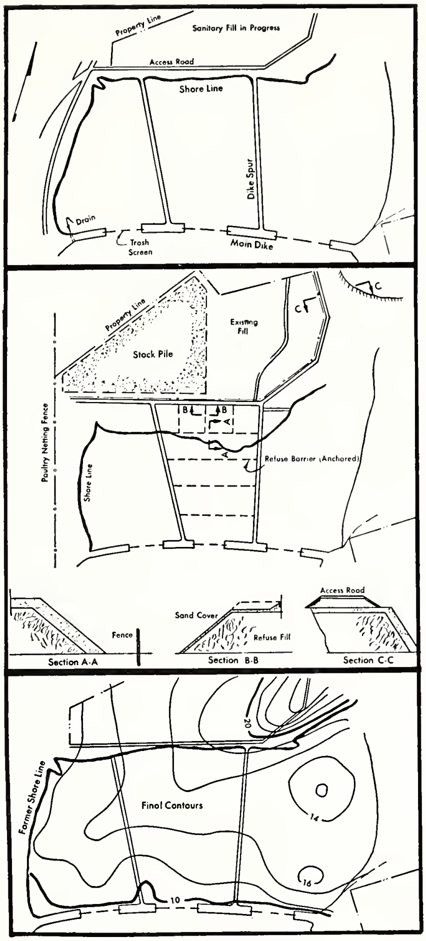
Tidal Areas

Tidal areas used as landfill sites should be divided into several lagoons by means of dikes to better control operations and limit and alleviate nuisances. Only one lagoon should be filled at a time. Each lagoon should be large enough to permit one winter's placing of the initial in-water layer of refuse. The initial in-water layer, built up during the winter, should have a compacted elevation of about 2 feet above maximum high water. (More than 2 feet may be necessary if high winds cause waves of much size at high tide.) The alternative—filling up to water level with clean earth—may be more satisfactory but much costlier.

Lagoon dikes should be strong enough to withstand mud waves and of such materials and proportions as to reduce permeability to the minimum. Malodorous leachings can be prevented entirely by watertight, shallow, lightweight, interlocking steel or wood sheet piling. Where strong currents or high waves are significant factors, outshore faces should be rip-rapped against erosion. Otherwise, flat grades or natural slopes may be a more economical solution.

Seattle has reportedly had good results in constructing dikes in marshy areas by using large masses of rubbish such as trees, tree limbs, lumber, and similar materials. Dikes built of such materials prevent mud and silt from sliding out from under the refuse fill. The large rubbish is brought in by private haulers and is placed by a tractor-dozer. The material, when compacted, is so interlaced and tightly bound together that cracking is reportedly almost unknown. Where pollution from leaching is a consideration, a dike should be constructed with an impervious core.


Residential Area
Property Line
Existing Dirt Road
Former Shore Line
Sand Cover Stock Pile
Hydraulic Fill
Trash Screen
Drain
C.L. of Dike
Berm
Strip to El. 0.0
Dike
U.S. Pierhead and Bulkhead Line
El. 22.0
El. 14.0
Poultry Netting
Berm Section
Dike Section
El. 6.0
Remove Sand and Use for Berm
Outshore Face
M.H.W. El. 0.0
10
Final Contours
10
0
6" Sand Cover
18" Sand Cover
Refuse Fill
Road
Fence
Berm


Property Line
Sanitary Fill in Progress
Access Road
Shore Line
Dike Spur
Drain
Trash Screen
Main Dike
Property Line
Stock Pile
Existing Fill
C
B
A
Refuse Barrier (Anchored)
Poultry Netting Fence
Shore Line
Access Road
Sand Cover
Refuse Fill
Fence
Section A-A
Section B-B
Section C-C
20
Former Shore Line
Final Contours
0
14
16
10

Figs. 45 and 46. The New York City Department of Sanitation fills wet areas in three steps: (1) site preparation; (2) construction of berm, barrier fence, and dike, and placing of fill in 150-foot wide strips; (3) site contouring. The plans at the left are for swampy and marshy areas; those at the right for a tidal area. In tidal areas, dikes and spurs divide the site into lagoons. Operational steps are much the same as those for swamps and marshes; the main difference is that in tidal areas the second step includes building anchored refuse barriers to help keep water in the lagoon clean.

The depth of the first layer of refuse should be the minimum, with deposition in strips, moving out with a pincer operation to confine underlying mud and avoid mud waves. Good compaction is essential to "key" refuse into muck.

Ponds, Quarries, and Similar Areas

Dumping refuse directly into large bodies of deep water such as ponds in quarries often causes nuisances. Biochemical activity of the putrescible component of the refuse creates anaerobic conditions and odors from the hydrogen sulfide given off during the process of decomposition. Relatively shallow ponds may be reclaimed by confining dumping to cold weather. The initial in-water layer should be at a depth slightly above high water during winter; warm weather filling should be limited to the secondary, overlying layers. An oxidizing agent such as calcium hypochlorite can be used to kill odors if there is not a lot of water.

Displaced water should be discharged at low velocities over adjustable weirs preceded by trash screens. A quiescent, shallow, near-uniform discharge will promote settlement of most suspended matter and will reduce carry-over of materials to the minimum. Heavy chlorination of effluent may be necessary, depending on temperatures, nature of receiving waters, and on other conditions.

Possible hazards of "sloughing-off" of refuse at the dumping face of wet fills cause some problems with equipment. Experience shows, however, that when the top of the first lift is at least two feet above maximum water level there is little risk of edge shearing or of losing equipment over the bank. Both rubber-tired and crawler equipment can work safely within a few feet of the bank. Mixed refuse, with its elastic components, interlocks and is also continuously compacted by the heavy operating equipment, developing angles of repose averaging 1 to 1, even when dumped into water.

EQUIPMENT AND PERSONNEL

Equipment and personnel required to operate a fill properly vary with the amount of refuse handled, characteristics of the site, and the fill method used.

Equipment

Four major types of equipment are used in operating sanitary landfills:

1. Track-type tractor that picks up and carries earth with a bullclam or front-end loader.
2. Track-type tractor with bulldozer (and scraper if needed).
3. Dragline.
4. Wheeled-type tractor with bulldozer and scraper.

The following are approximate needs for tractors with a front-end loader or bullclam:

Cities of up to 15,000 population need 1 unit of 1 cubic yard capacity; cities between 15,000 and 30,000 population need 1 unit of 2 cubic yards capacity; cities between 30,000 and 75,000 population need 2 units of 3 cubic yards capacity.

If it is necessary to haul cover material 200 to 500 feet, the use of a wheeled scraper in conjunction with a tractor-dozer should be considered in communities of 30,000 to 100,000 population. A bulldozer and dragline may be used for a fill in an area in which a water table, for instance, prevents operation of a tractor at the base of the fill. The dragline can operate from firm footing on top of the fill and at the same time get cover material. A bulldozer is used to place and compact the refuse and cover.

Wheeled-type tractors are useful at sanitary landfills where especially long hauls on the site are required to provide the cover material. They are usually used with track-type tractors that place and compact the refuse; they are also usually considered for large fills. Under some circumstances they have special advantages because they can move from one site to another and over paved highways under their own power.

To make cost estimates of landfill operations, it is necessary to know how much refuse various kinds of equipment can handle a day. The Los Angeles County Sanitation District made a survey of refuse collection practices among large cities in the western and southwestern states. From the data gathered on equipment usage, the quantity of refuse handled by a piece of equipment was calculated for each landfill operation reported upon. A comparison of the figures reveals an apparent upper limit for the quantity of refuse a unit of equipment can handle.

The survey showed that two landfills operated by the City of San Diego each received about 250 tons of combined rubbish a day, each site operating with one 47,000-pound, 180 drawbar horsepower bulldozer full time and another part time. A privately operated landfill in Los Angeles receives about 700 tons of refuse a day and operates with two 180 drawbar horsepower bulldozers full time and one 180 drawbar horsepower tractor and carryall scraper part time.

In Seattle, the survey revealed, where landfills are operated on a contract basis, experience indicates that a landfill requires the use of a bulldozer with 180 drawbar horsepower when 2,000 cubic yards or more of fill a day are handled, 102 drawbar horsepower when 1,000 to 2,000 cubic yards a day are handled, and 75 drawbar horsepower when up to 1,000 cubic yards a day are handled. The equipment places and compacts the refuse as well as the earth cover that is brought in by truck from other sources.

Based on experience at these landfills, one bulldozer of the 180 drawbar horsepower class and 47,000-pound gross weight size can adequately handle about 250 tons of refuse a day, assuming that excavation for cover presents no special problems and that the cover is hauled no more than 100 yards to the working face. If a ripper is used to loosen cover material for excavation or if a long haul requires a carryall scraper, the quantity of refuse put in a landfill per bulldozer decreases. If a landfill receives many times 250 tons of refuse a day and uses several bulldozers for its operation, the efficiency of each unit can be increased by specializing and coordinating functions.

The Mission Bay cut and cover site operated by the City of San Diego receives about 250 tons of refuse a day, which is adequately handled by a dragline with a 1½-cubic-yard bucket and a 180 drawbar horsepower bulldozer. At another cut and cover landfill, operated by the City of Fresno, a dragline with a 1½-cubic-yard bucket is used five days a week and a 75 drawbar horsepower bulldozer one day a week to dispose of about 220 tons of refuse a day.

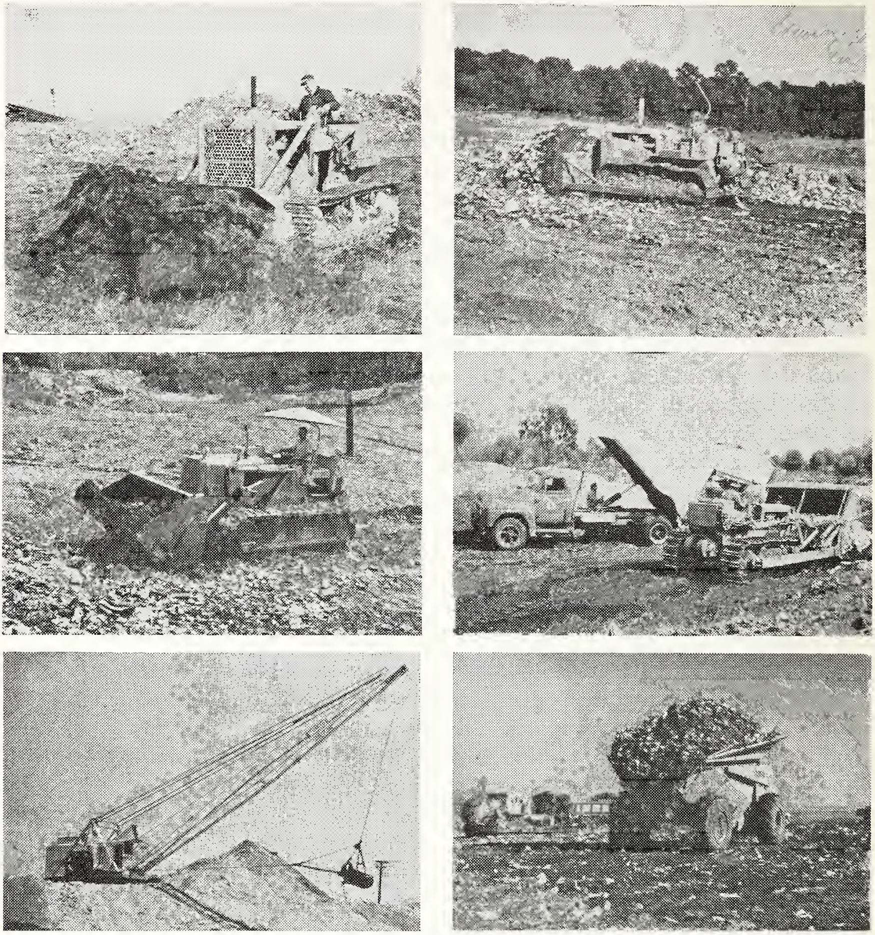


Fig. 47. Various kinds of equipment are needed for sanitary landfill operations. Top are an HD11 Allis Chalmers crawler tractor with front-end loader, and a D-7 Caterpillar crawler tractor with bulldozer; middle, a TD15 International Harvester crawler tractor with a Drott four-in-one leader, and a TD14A International Harvester crawler tractor with a Drott bullclam; bottom, a Bucyrus Erie dragline, and a Le Tourneau large capacity rubber-tired "over landfill" hauling unit.

Based on reports of cut and cover operations, from 5½ to 17 equipment hours per 1,000 cubic yards of refuse may be required. At Riverside, California, two tractors, one equipped with a dozer and the other with a bullclam, require eight hours of equipment time per 1,000 cubic yards of refuse handled.

Accessory Equipment. Various types of accessory equipment may also be necessary for a landfill. A ripper may be required if the cover material is difficult to excavate; a carryall scraper if the cover material must be moved more than 150 to 200 yards; a power shovel for operations involving rocky and gravelly soil; a sheeps-foot roller if roads must be built on the fill; a water truck to control dust; and an extra bulldozer as a pusher to assist in loading carryall scrapers. Provision should also be made for standby equipment that can be used if regular equipment breaks down. In many instances it is also advantageous to have spare parts available.

Several patented landfill machines are available that are used in conjunction with a crawler-tractor to combine the advantages of a bulldozer with the versatility of a skiploader. These devices are particularly useful on small landfill projects where only one piece of equipment is required and flexibility of function is a necessity. These devices can be used with almost any size crawler-tractor, making it possible to match equipment to capacity. Pneumatic-tired bulldozers are manufactured that may be useful in operating landfill projects, although there is some reluctance to risk rubber-tired equipment on rubbish fills. A grid-type roller compactor is also produced that may be applicable to refuse compaction. Some of these machines have not yet been tried on large-scale landfill projects.

An adequate water supply at a landfill project is necessary, and sprinkling equipment is desirable at sites that have extremely fine soil or that are close to inhabited areas.

Equipment Planning. Planning the amount of equipment needed for a fill requires detailed plans and specifications of each step. The type and number of pieces of equipment vary with the size of the operation and other local conditions.

The following are typical equipment needs for a landfill handling about 300 truck loads of refuse each 24 hours (15 cubic yards each at about 3½ tons per load) with a 200-foot wide by 20-foot deep open space, in a city of 400,000 to 500,000 population:

1. Two 20-ton bulldozers, diesel engine driven, crawler or pneumatic-tire type; one to be used at the face of the fill to push and distribute the refuse over the bank; the other for grading, covering, road building, fire fighting, and other work, and as a standby.
2. Two 15-cubic-yard, self-loading, self-dumping tractor-drawn scrapers. Both are required for digging and carrying cover material from the stockpile to the dumping area and for continuous spreading and covering of the refuse. If cover material must be cut from a distant borrow pit, a power shovel and one or more dump trucks, depending on the distance of haul, are needed to augment the scraper. The power shovel is also required for construction of drainage ditches, berms, and culverts.
3. One street flusher, or its equivalent, for spraying deodorants and for fighting fires if municipal water supply is not available.

Personnel

Data reported by the APWA indicate that six men, on the average, are required for each 1,000 cubic yards of refuse disposed of each day in a sanitary fill. The primary variable is the kind of site. Manpower requirements reported to the APWA vary from 10.6 men per 1,000 cubic yards of refuse per day at St. Petersburg, Florida, where tidal land was being reclaimed, to 3.3 men per 1,000 cubic yards per day where conditions were more favorable.

At Seattle landfills in which a single contractor dumps refuse (collection and disposal is by contract), only equipment operators and one "dump" man are required. If in addition to the contractors, individuals also are allowed to dump refuse, the manpower requirements are about five "dump" men in addition to the equipment operators.

Data on landfill operations reported by 138 cities show that all except 34 cities with populations of 15,000 or less operate fills with one man; of 38 cities with more than 15,000 but less than 50,000 residents, 15 used 1 man to run the entire fill operation, 18 used 2 men, and 3 reported they used 3 men. The point at which it was necessary to go from using one man to two men varied widely but that point was usually reached in cities in the 16,000 to 25,000 population category. Of 14 cities with more than 50,000 but less than 100,000 population, 7 reported operating fills with 2 men, 5 with 3 men, and 2 with more than 3 men.

Costs

A wide range of costs for sanitary landfill disposal have been reported. The total cost of a fill is the sum of land costs plus site development costs, plus operating and equipment costs, plus landscaping and maintenance costs.

From the long-range point of view, the cost of the land for the site is small; land in a metropolitan area used for fills usually increases in value when the fill is completed; and land in remote areas used for disposal sites may cost less than 1 cent per ton of refuse disposed of. Typical costs of a landfill site in the Los Angeles metropolitan area are 3 cents a cubic yard or about 10 cents a ton of refuse disposed of. If the market value of the site increases or decreases after completion as a fill, the 10-cent-a-ton figure must be adjusted accordingly. In the Los Angeles area in the late 1950's land for a fill should not have cost more than $1,000 an acre; or about 10 cents a ton of compacted refuse for a 15-foot depth. However, in small cities and towns it could be bought for as little as a few dollars an acre. Costs vary for each site, of course, and should not be estimated without an appraisal of each one.

The cost of site development can be analyzed from factors already discussed. Expenditures include those for access roads, water supply, fences, firebreak clearance (if required), landscaping, surface runoff diversion facilities, weighing devices, and an office and equipment shed. The person planning the fill can usually estimate site development costs quite accurately on the basis of physical factors, reasonable standards, and the requirements of government agencies.

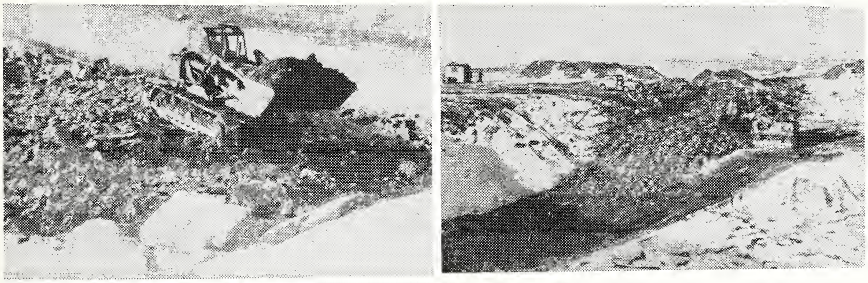
With landfill projects serving a city of 50,000 or more persons, it is possible to use equipment advantageously in relation to the amount of refuse disposed of, so that operating costs for a "large-capacity" site are not materially different from those for one of "small capacity." There are so many different methods of operation for landfills, however, that operating costs for large landfills vary widely from place to place.

Experience shows that sanitary landfills are operated for from 50 cents to more than $2 a ton of refuse handled. The total includes costs of land, equipment, depreciation, labor, operation, and contingencies. The average cost in 1959 was approximately $1 a ton of refuse delivered to the site. The many variables in operations and how they affect costs are discussed in Chapter 11, Management of Disposal Facilities.

Special Problems

Winter Operations

Sanitary landfills can be operated in the United States throughout the year, even in extremely cold climates. A landfill was operated as an experiment in Mandan, North Dakota, through the winter of 1949 during which temperatures dropped to as low as 44 degrees below zero. The Mandan project has been continued successfully since and many other cities have also successfully operated landfills under similar climatic conditions.



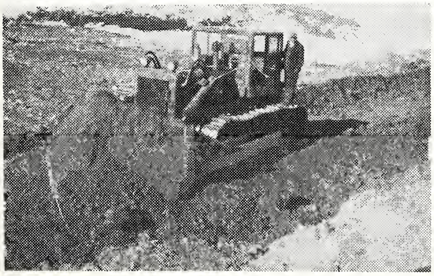


Fig. 48. Even in North Dakota, sanitary landfills can be operated during the winter. In Mandan (upper left), chunks of frozen earth crust are common; in Bismarck (upper right), earth cover material is stockpiled; and in Minot (left), excavations are made through the winter.

On the basis of experience with the Mandan project (in relatively sandy soil), the following recommendations for year-around operations in an extremely cold climate have been made:

1. Scarify the area for winter operations before there is a frost and insulate the ground with leaves or similar material (2- to 3-foot depth).

2. Excavate trenches in advance of cold weather and stockpile cover material for use during the winter.
3. Excavate an "undisturbed area," if possible. (An "undisturbed area" is one that has not had the vegetation and earth compressed by, for example, numerous trucks driving over it. "Undisturbed areas" have been successfully used for fill sites in Bismarck, North Dakota.)

It is also recommended that tractor equipment for winter weather operations include ice and snow grousers and a heated cab for the operator. A heated garage for equipment storage and headquarters for personnel are necessities.

Wet Weather Operations

Wet weather operations give rise to problems because maneuverability of trucks as well as landfill equipment is often seriously impeded. The following recommendations have been made on the basis of wet weather operations:

1. Use well drained sites with sandy loam soil if possible.
2. Build all-weather access roads.
3. Stockpile such materials as ashes or planking for construction of firm surface lanes from the permanent access road to the area of operation.
4. Dump refuse some distance from the operating face of the fill and bulldoze it to the area of operation under extreme conditions. This practice is advocated in most cases only as a final resort.
5. If a load is not prohibitively heavy, a tractor sometimes can tow refuse trucks to the operating area. (Care must be taken not to damage the trucks, however. On one fill, a dozer pulled the whole front end off of a mired vehicle.)
6. Use other sites during prolonged wet periods. In certain places, such as New Orleans, use of alternative sites is a common practice.

Techniques for handling wet weather problems vary, of course, according to the location of a fill site.

Dust

Dust can be effectively allayed by periodically sprinkling the site with water. On large operations a tank truck may be assigned to the fill site. In New York City fences surrounding some sites are designed to help control dust. Oiled paving or the use of calcium chloride minimizes dust from traffic on access roads.

Odors

Odorous gases are the products of surface putrefaction of deep-seated anaerobic digestion. Ponds with churned-in, high organic content, polluted stagnant drainage ditches, and leaching from refuse piles are sources of anaerobic decomposition gases. But properly operated landfills are free of odor, and prompt action can forestall complaints from the public if odors do become a nuisance.

The following are recommended to keep odors to a minimum:

1. Rapidly and continuously cover freshly dumped refuse, particularly garbage.
2. Seal surface cracks in completed areas of the site to prevent emission of gases.
3. Eliminate surface pools, side leaching action, and seepages at toes of filled embankments.
4. Spray the refuse with suitable deodorants if required.

An emulsion of orthodichlorbenzine, 1 part to 125 parts of water, has been found satisfactory as a deodorizing agency. It is largely a masking agent, with some larvicidal properties. It can be sprayed with a conventional fire hose and nozzle at a rate of about 6,000 gallons an acre; the moisture added by spraying promotes more rapid digestion and stabilization of the putrefiables.

Fresh refuse seldom has the unpleasant odor of putrefying material. Therefore, adequate and frequent collection is extremely important. Collecting garbage twice a week during warm seasons, careful wrapping of garbage by the householder, and promptly getting it into the fill should be sufficient to control garbage odors, for practical purposes, at most landfill operations.

Fire

Fires in freshly dumped refuse or even within a completed fill are possibilities to be reckoned with. Fires in fills are caused by carelessness, by dumping hot ashes or incinerator residue, by spontaneous combustion, and by the presence of highly flammable materials.

When near the surface of a fill, fires can be extinguished by spraying with water, either from large, especially designed mobile tanks or street flushers, or from street hydrants. Deep-seated fires can best be brought under control by excavating them with bulldozers or draglines for surface exposure and spraying. Both surface and deep-seated fires may at times be extinguished economically and successfully by smothering with an impervious blanket of earth.

Fire hazards are negligible on landfill operations in which recommended compaction techniques are used because oxygen required for initial combustion is limited in a well-compacted and covered fill. Good practice calls for earth cover on the face of the fill at the close of each day's operation, which, in effect, creates individual cells that confine a fire, if it does start, to a relatively small area.

Disposal of large quantities of brush, logs, and tree stumps in a sanitary fill is difficult because they are bulky and hard to compact. Sometimes they are burned and the ashes dumped into the fill. If they are, the burning should be done away from the immediate operating area of the fill, or, if quantities justify, even at a completely different site. In cities in which stringent air pollution control ordinances are enforced, this practice is not permitted, however, and it may be necessary to use wood hogs to cut up the brush, logs, and stumps so they can be put in the fill.

A water system with at least 30 pounds per square inch pressure is necessary for fire control at a fill site. The system should have a minimum of a 1½-inch diameter line or a 5,000-gallon storage reservior or tank. A pond or stream may be used as a storage reservoir, but reliable pumps of adequate size must be available.

Ground and Surface Water Pollution

The possibility that a sanitary landfill will pollute ground and surface waters in the area of the fill must be considered. A number of investigations have been made in recent years of the physical "behavior" of landfills and the effects of leachate from fills on underlying ground waters. Briefly, the reports of these studies say:

For pollution of ground water by refuse leaching, three conditions must exist: (1) the site must be over or adjacent to an aquifer; (2) there must be supersaturation within the fill caused by the flow of ground water into the fill from percolation of precipitation and surface water runoff, by water of decomposition, or by an artificial source; (3) leached fluids must be produced and the leachate must be capable of entering an aquifer.

If sound engineering practices are followed, a site that has both conditions one and two would not be selected for the fill. Condition three can be brought about by a combination of water used for refuse compaction (as at the San Diego landfills), water of decomposition, rainfall, and surface runoff. It is highly improbable, however, that any of them except compaction water would provide sufficient moisture to produce supersaturation in the fill. After a site is filled and the area reclaimed, the surface sources of water for leaching are rainfall, runoff, and irrigation; subsurface sources are high ground water levels due to artificial or natural recharge of aquifers and breaks in water mains and sewers.

An investigation at the University of Southern California in which bins filled with rubbish-garbage mixtures were used for tests showed that a total of 15 inches of water applied at the rate of 1 inch a day is necessary to saturate the fill material and produce free water or leachate. Based on a bin depth of 10 feet, the water amounted to approximately 25 gallons per cubic yard of fill, or approximately 65 gallons per ton. It has been determined experimentally that paper and paper products, which constitute approximately 40 per cent of combustible residential rubbish, can absorb 250 per cent to 300 per cent water by weight. Considering also that the average moisture content of typical mixed refuse (including garbage) is only 45 per cent to 50 per cent, it is obvious that a landfill can absorb large quantities of water without becoming supersaturated. In the investigation, a bin of rubbish identical to that to which water was added had no moisture added and produced no leachate, indicating that the water of decomposition plus three inches of rainfall during the five months of the investigation were not in excess of what the fill could absorb.

In experiments in San Diego the amount of water used to aid in compaction of a landfill amounted to an estimated 385 gallons per ton of refuse—more than six times the amount used in the University of Southern California test bin to obtain leachate. The addition of such large quantities of water to a landfill for compaction is not recommended for sites in which there is a possibility of ground water contamination, however.

If leaching of a landfill does occur, the ground water in the immediate vicinity of the fill—approximately 1,000 feet downstream—can become grossly polluted, unfit for human and animal consumption or for industrial and irrigation uses.

The effects of pollution may be classified as physical, chemical, and biological. If essentially anaerobic conditions (absence of oxygen) exist in a landfill, the decomposition of organic matter results in the formation of gases—principally methane, carbon dioxide, ammonia, and hydrogen sulfide. Methane, due to its slight solubility and low density (specific gravity, 0.55; specific gravity of air, 1), diffuses vertically. Hydrogen sulfide, even when present in relatively small amounts, gives leach-polluted waters an offensive taste and odor; however, by dilution with oxygen containing ground water and from atmospheric oxygen diffusing into the landfill, sulfides are oxidized to tasteless and odorless sulfur and sulfates.

Carbon dioxide, due to its high solubility, combines with water to form carbonic acid, which will dissolve iron from tin cans and lime from calcareous materials and deposits. The leachate cannot, however, contain both ferrous iron and sulfides. Chemically, the effects of carbon dioxide, by increasing the hardness and the effects of ammonia on oxidation and by increasing the nitrate content, are the most significant products of decomposition of organic matter in a landfill operation.

In the University of Southern California investigation the leachate from the test bin to which water was applied contained in excess of 200 parts per million (ppm) ammonia and organic nitrogen, with peaks of 845 ppm ammonia nitrogen and 550 ppm organic nitrogen. As one part of organic or ammoniacal nitrogen can produce 4.43 parts of nitrate, the concentration present in the leachate, and potentially in lesser amounts in polluted ground water, can thus exceed by many times the 10 to 20 ppm concentration of nitrate nitrogen in water safe for infant consumption. Excess nitrates are also undesirable in the water supply for certain industries and in irrigation water in certain soils, since excess nitrates tend to reduce soil permeability. Their value as a fertilizer probably outweighs their undesirable properties, however.

Pollution of ground water by bacteria from leaching of landfills might seem to be of prime importance. It has been shown, however, that coliform (intestinal) organisms, commonly used as indicators of sewage contamination, even when present in high concentration in sewage effluent as applied to "spreading" grounds for water reclamation, are seldom found below four feet and never below seven feet, even in highly permeable soil. It has been shown that pumped recharge of polluted waters to underground aquifers results in travel of bacteria for less than 100 feet. Considering that it is accepted practice to locate cesspools as near as 300 feet to water wells, safety against bacterial pollution of ground water by leaching of landfills is assured if water is not pumped from a point immediately adjacent to the fill site.

In summary, only where landfills become supersaturated because of artificial wetting, inadequate drainage of surface runoff from the site, or inundation by high ground water is the threat of ground water pollution real. The problem is complex enough, however, to require the investigation and judgment of competent sanitary engineers on whether a landfill could cause contamination. Since the problem is regional in scope, the responsibility for control of pollution should be delegated to a competent government agency, such as the state or local health department or a water pollution control authority. That agency should establish criteria to determine pollution possibilities.

Responsibility for defining reasonable and beneficial use of the natural waters in California is given to regional water pollution control boards. The regional boards review the geological and hydrological factors affecting each proposed landfill site and set criteria for water quality that allow reasonable uses of the natural waters consistent with acceptable standards. For convenience in considering landfill sites, Water Pollution Control Region No. 4, which has jurisdiction in the Los Angeles and Ventura watershed areas, has established the following classifications:

A. CLASSIFICATION OF DISPOSAL SITES

From consideration of the geology, hydrology, topography, nature of wastes and other pertinent factors, three general classes of disposal sites are established:

(A) CLASS I DISPOSAL SITES

Sites located on non-water-bearing rocks or underlain by isolated bodies of unuseable ground water, which are protected from surface runoff and where surface drainage can be restricted to the site or discharged to a suitable wasteway, and where safe limitations exist with respect to the potential radius of percolation.

(B) CLASS II DISPOSAL SITES

Sites underlain by useable, confined, or free ground water when the minimum elevation of the dump can be maintained above anticipated high ground water elevation, and which are protected from surface runoff and where surface drainage can be restricted to the site or discharged to a suitable wasteway.

(C) CLASS III DISPOSAL SITES

Sites so located as to afford little or no protection to useable waters of the State.

B. NATURE OF WASTES ACCEPTABLE FOR DISPOSAL AT CLASS OF DISPOSAL SITE

This list is not intended to be complete or comprehensive but rather an indication of the nature of wastes acceptable at each class of disposal site. Materials, other than those listed, may be considered separately by the interested governmental agencies and the Regional Water Pollution Control Board.

(A) CLASS I DISPOSAL SITES

No limitation as to either solid or liquid wastes.

(B) CLASS II DISPOSAL SITES

Limited to ordinary household and commercial refuse and/or rubbish, garbage, other decomposable organic refuse, and scrap metal of the nature indicated below at safe elevations above anticipated high ground water elevation in the vicinity of the site:

a. Empty tin cans
b. Metals
c. Paper and paper products
d. Cloth and clothing
e. Wood and wood products
f. Lawn clippings, sod, and shrubbery
g. Hair, hide, and bones
h. Small dead animals
i. Roofing paper and tar paper
j. Thoroughly quenched ashes from high temperature incinerators
k. Unquenched ashes mixed with refuse
l. Market refuse
m. Garbage
n. All material acceptable at Class III Disposal Sites without regard to elevation of anticipated high ground water

(C) CLASS III DISPOSAL SITES

Limited to non-water soluble, nondecomposable inert solids of the nature indicated below:

a. Earth, rock, gravel, and concrete
b. Asphalt paving fragments
c. Glass
d. Plaster and plaster board
e. Manufactured rubber products
f. Steel mill slag
g. Clay and clay products
h. Asbestos shingles

To minimize the possibility of underground pollution, the Illinois public health department has made the following recommendations (Idaho's are similar):

(a) Do not build on exposed rock strata. Keep a minimum of 30 feet clay-till overburden between strata and refuse, unless studies indicate that a lesser depth is satisfactory.

(b) Locate fill at least 500 feet from drift wells, unless studies indicate that subsurface seepage is not imminent.

(c) Do not place garbage and refuse in mines or other areas where resulting seepage or leachate may carry waste to water-bearing strata or wells. Remember that chemical pollution may emanate from a fill and probably will travel for long distances as compared to organic and bacterial pollution travel.

(d) Do not locate sanitary fills on or near springs.

(e) Consult the state department of reclamation, state geologist, and the state department of public health regarding any problems of possible underground pollution.

SETTLEMENT AND DECOMPOSITION

Settlement

The amount that a sanitary landfill settles depends primarily on what kind of refuse is used and how thoroughly it is compacted. Reports of experience in 58 cities with fill depths varying from 4 feet to 20 feet show that 29 cities had only slight settlement and the other 29 had settlements of from 1 per cent to 25 per cent after two years. The average amount of settling reported was 11 per cent after two years.

Settlement generally varies from 10 per cent to 25 per cent within six months to two years, depending on compaction techniques. If the refuse is compacted in thin layers of one to two feet as it is placed, the percentage of settlement will probably be low and the site can usually be used for recreational purposes two years after its completion, although periodic maintenance may be necessary for parts of the site that settle unevenly.

The City of Richmond, Virginia, has operated landfills since 1947, reclaiming swamps and waste land for parks and playgrounds. The city operates as many as six landfills concurrently, placing refuse in layers ranging from 6 to 15 feet deep; 5 to 10 per cent settlement has been observed in them after five years.

In New York, where landfills have layers of refuse from 15 to 20 feet deep, it was found that initial shrinkage in dumped refuse is caused by

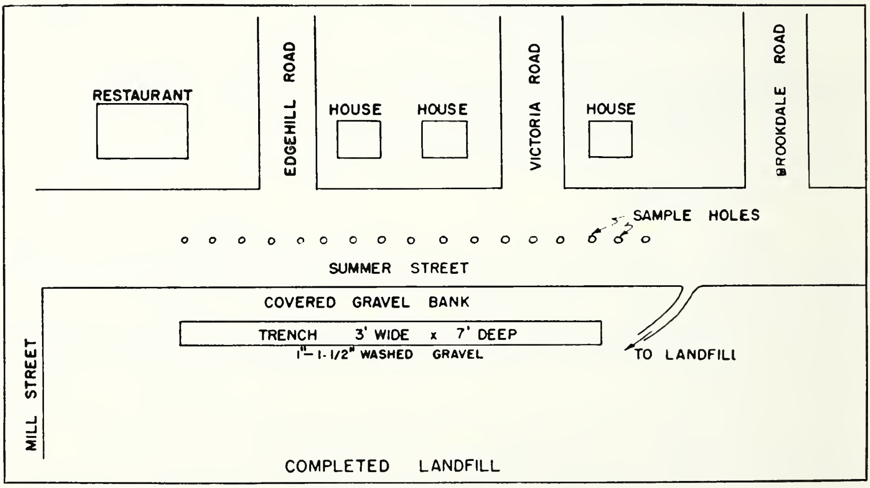

RESTAURANT
EDGEHILL ROAD
HOUSE
HOUSE
VICTORIA ROAD
HOUSE
BROOKDALE ROAD
SAMPLE HOLES
SUMMER STREET
COVERED GRAVEL BANK
TRENCH 3' WIDE x 7' DEEP
1"–1-1/2" WASHED GRAVEL
TO LANDFILL
MILL STREET
COMPLETED LANDFILL

Fig. 49. A hazard of improperly engineered sanitary landfills is accumulation of methane, a gas resulting from decomposition of refuse. When a fill site in Arlington, Massachusetts, was oiled and the cover of the fill thereby sealed, methane gas flowed laterally through a gravel bank toward residences, rather than vertically and harmlessly through the cover of the fill. A washed gravel trench was constructed, as shown above, to intercept the gas and permit it to escape into the atmosphere.

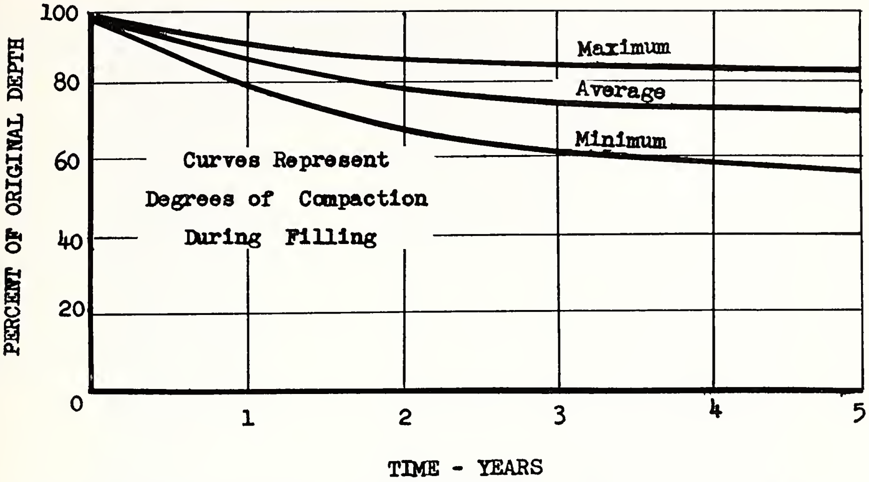


Fig. 50. The chart shows the rate at which the surfaces of completed sanitary landfills settle.

compaction from heavy equipment and the weight of the refuse and cover. Initial settlement reduces 2 cubic yards of truck material to 1 cubic yard in the fill; there is subsequent shrinkage from filling in voids left when semi-compacted tin cans rust out and organic material in the refuse decomposes. There may be even further subsidence from compression or shifting of subsoils and from expulsion of entrapped waters, particularly in water-logged, silty soils. Subsequent compaction and settlement eventually causes 3 cubic yards of refuse in the truck to be reduced to 1 cubic yard in the fill. It was found in New York that about 90 per cent of the total settlement occurs in the first 2 to 5 years. The remaining 10 per cent may be over such a long period that it has little bearing on the grade planned for the site. Usual practice is to make the initial compacted grade of a fill about one-third higher than that required. Settlement of the fill, decreasing in rate from about 15 per cent the first year to 6 per cent the second and about 3 per cent each of the next 2 to 4 years, will eliminate the 33 per cent overfill.

Fills on marshy lands, in boggy areas, and in ponded or open waters settle more and at a faster rate than fills on dry land because of accelerated decomposition, subsurface subsidence, mud wave displacements, and, sometimes, leaching action.

Many landfills must be checked periodically, depending on local conditions. In any event, fills must be regraded occasionally and the surfaces must be maintained until the fill has become reasonably stable.

Decomposition

Decomposition of landfills depends on many factors, including permeability of cover material, depth of burial and rainfall, moisture content and putrescibility of the refuse, and degree of compaction.

In Richmond, Virginia, and in New Orleans refuse in landfills has reportedly been decomposed in three to four years. As a general rule, however, climatological and operational conditions are such that much slower decomposition may be expected.

Garbage and rubbish are made up principally of carbohydrates, fats, and proteins. The elements of carbon, oxygen, hydrogen, nitrogen, and sulfur are most prevalent in organic refuse. Refuse in sanitary landfills decomposes slowly through the anaerobic process of decomposition. Microorganisms of the soil and refuse are responsible for this decomposition. The organic acids of decomposition tend to pickle refuse, especially in deep fills. After many successive breakdowns through the feeding and growth of microorganisms and the action of their enzymes, the end-products are gases and humus material. The gaseous end-products are represented by the diagram in Figure 51.

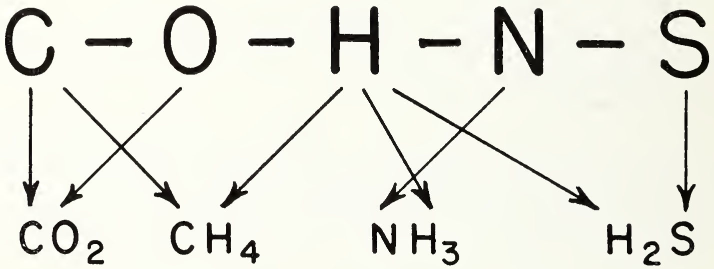


Fig. 51. Carbohydrates, fats, and proteins, plus microbiological fermentation produce gaseous end-products and humus.

Decomposition occurs anaerobically at elevated temperatures. In a series of studies of landfills made in New York in the late 1930's, temperatures up to 160° F. were generated by the microorganisms operating within the fill. On the basis of subsequent investigations, however, it appears that average temperatures attained in a sanitary landfill may be much less—from 100° to 120° F.

Methane (CH_4) and carbon dioxide (CO_2) are principal gases produced during the process of degradation of refuse in a fill. Studies of a Seattle landfill, made by the University of Washington, indicated that the greatest amount of gas is produced from refuse that is about one-half to two years old if the refuse was placed in layers 20 to 40 feet deep or if there are two or more 8-foot layers. It was also observed that gas production was slowed as the moisture content of the refuse decreased. If completed cells settled below the water level of a swampy area or if surface water percolated into the refuse, gas production increased.

Waste gases were burned at a Seattle fill where earth cover was inadequate (see Figure 52) to eliminate odors. It was found that the static gas pressure developed in the burners was low (equivalent to about

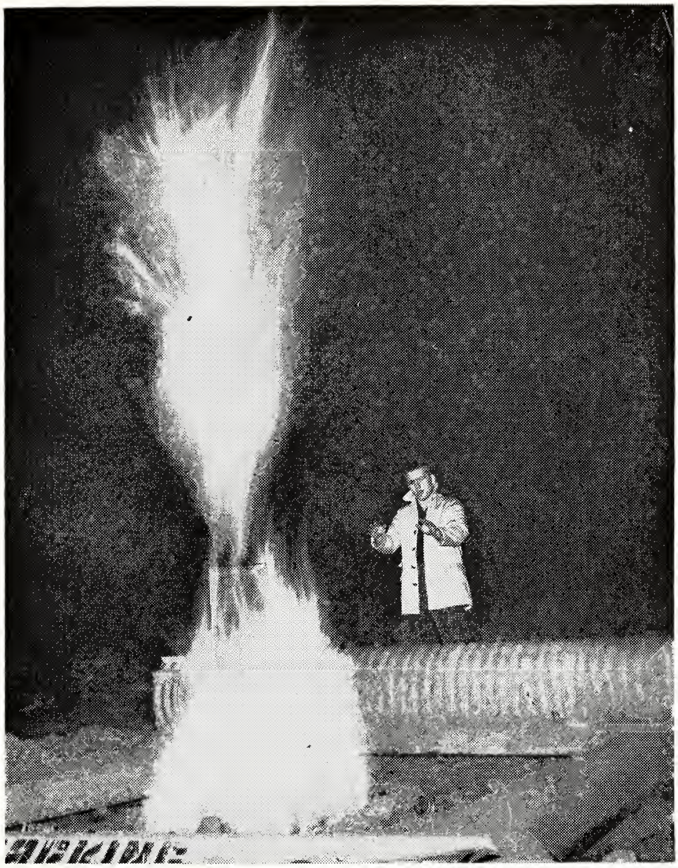


Fig. 52. Studies by the University of Washington indicate that controlled burning of waste gas at a sanitary landfill may be an effective way to control odors where the earth cover is inadequate to do so. This burning of gas was done at the Union Bay landfill in Seattle.

½-inch of water) and an "average" burner was found to give off about 0.7 cubic feet a minute.

On one landfill, workers drove a one-inch pipe into a decomposing section of the fill, fashioned a tip on the upper end of the pipe, and lighted the gas coming off, providing a continuous flame for boiling coffee. This gas may be explosive, of course, if trapped in an enclosed space.

Explosive mixtures have gotten into structures built on landfills; the gases have seeped out of the fill and upward along an insulated water or sewer pipe from the fill to an enclosed space in the building. A spark from an electric fixture is all that is needed to ignite the gas. For this reason, all buildings on landfills must be completely vented between the building floor and the landfill surface. A granular material such as crushed stone or slag should be placed over the fill to permit uniform diffusion of gas into the atmosphere.

Hydrogen sulfide is not a problem ordinarily on dry landfills. The diurnal entrance and exit of sea water high in sulfates into tidal marsh fills, however, may lead to a serious problem from the action of sulfates, which reduce bacteria and which in turn produce sulfides. Diking should be used outside the fill to prevent sea water from going in and out of the fill. A similar problem may arise if a sulfate-containing stream of water passes under or from the fill. The flow of water should be ditched around the fill to prevent contamination.

Other aspects of decomposition are incidental and may have no effect if a landfill site is used as an open area such as a park or storage lot; however, decomposition will affect settling of building foundations. Time of decomposition in unknown. Landfills excavated 25 years after completion have revealed that many materials are virtually unchanged, particularly those that are cellulose, suggesting that fills ordinarily cannot be expected to undergo complete decomposition for generations.

Uses of Completed Landfills

Land reclaimed by landfill disposal operations can be a valuable asset to a city. Many uses—parks, playgrounds, golf courses, parking areas, landing fields, light industrial or commercial buildings—are suitable for completed fills. The use of a site may be restricted by its surroundings, however, and to some extent by the amount of settlement in the fill. A fill several miles from a residential district is not a desirable site for a playground or parking area, and a fill that can be expected to settle rapidly and unevenly is not suitable even for light construction. If a suitable use is decided upon for a fill site before the fill is begun, the method of operation and degree of compaction can be planned to provide for the needs of that use.

Recreation and Parking Facilities

Parks, playgrounds, and ball fields are the most popular uses for landfill sites. Two feet of well compacted final cover is sufficient for most parks and playgrounds. If trees or large shrubs are to be planted, a deeper final cover may be necessary.

If a site is to be used for a golf course, plans for the finished surface should be decided upon in time to allow fashioning the topography with refuse lifts. Landfill sites used for parks differ only in surface configuration of final grades from those used for golf courses. Degree of refuse compaction, depth of final cover, and other factors are the same for either use. Montebello, California, has a police department-sponsored playground on a completed landfill site; a land reclamation park in Burbank, California, provides both park facilities and access roads to other facilities.

The amount of settlement at a landfill site that is to be used for a parking lot is more important than the amount at a site to be used for a

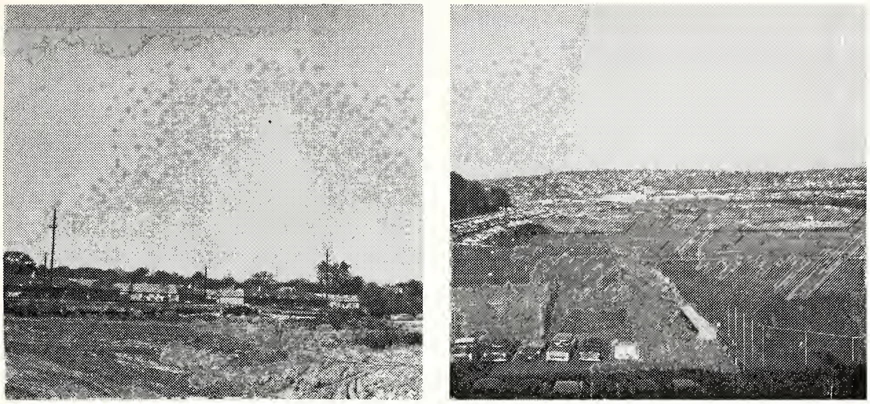


Fig. 53. Landfill sites have been used for many purposes. Landfilling has been used to raise the level of the site at the left for a recreation area for nearby residents; another fill, on University of Washington property in Seattle, is used for parking facilities.

park or playground. If any appreciable settlement occurs after a parking lot has been paved, the paving may crack and drainage may be affected. A final cover of 2 feet on a parking lot site is sufficient if the cover, as well as the underlying refuse, is well compacted. Flexible paving (bituminous binder) is ordinarily recommended for parking lots on landfills.

Parking facilities and stables have been built on tidelands reclaimed through landfills near the Golden Gate race track on the eastern shore of San Francisco Bay. Reclaimed areas also are used as industrial building sites in the Bay area. Sand pits reclaimed by landfilling in Dallas, Texas, are now used by a car-transport company and for recreational purposes. In Richmond, Virginia, parking lots for shopping centers have been constructed on completed fills. More than 10,000 acres of tidal and marshy land in New York have been reclaimed; streets, parks, airports, industrial buildings, and large housing developments have been built on it.

Buildings

It is of utmost importance to understand that construction on completed refuse fills can be hazardous if the requirements peculiar to construction on fills are not followed, and that the site may be odorous if the fill is not properly made. Furthermore, although there are many reports of successful construction on fills, further research is needed in the field to encourage more extensive and better use of completed landfill sites.

A landfill upon which buildings are to be constructed should be as stable as possible. A well compacted final cover 2 or 3 feet deep over a fill of well compacted refuse should settle no more than 5 to 10 per cent (as in Richmond, Virginia, and other cities). Housing has been built satisfactorily on such fills in Dallas and Richmond, although in Richmond there was some trouble with settlement cracks in foundation concrete slabs. If settlement after construction is anticipated, special attention must be given to the design of sewer and water lines to prevent them from breaking or drainage from being reversed. Foundations and footings should be conservatively designed and no rigid or stucco construction should be used.

Completed landfills provide inadequate support for heavy construction; however, either conventional pile or raft-type foundations, required in any event for an underlying marshy, silty subbase, will normally be satisfactory.

Guides for Construction. Since fills made with ashes, construction wastes, or similar inert materials pose few construction problems and since fills are seldom made of garbage only, the concern is with construction on fills made of mixed refuse.

The following rules, recommended to the 1959 American Public Works Congress,[3] were formulated to help prevent hazards of methane gases in buildings on filled sites. They are based on the concept that:

1. The subsurface gases could be intercepted and dissipated harmlessly into the atmosphere through venting by means of suitably designed porous, gravel filled trenches or by pipes inserted into the body of the fill.
2. The discharge of landfill gases into structures could be arrested by means of subsurface enclosing envelopes of gas-tight construction.

It was recommended that all structures built on land filled in part or in whole with putrefiable material or that may possibly have been filled with putrefiable material must meet the following minimum requirements:

Houses:

A. No cellars, basements, crawl spaces or similar open spaces shall be permitted below finished grade.

B. The ground floor shall be at least 1 foot above finished grade and shall be of permanently gas-tight construction. The fill immediately underneath shall be of nonporous materials to a depth of 24 inches.

C. All pipes, ducts, and conduits piercing the ground floor shall have gas-tight gaskets of an approved permanent nature.

Multiple Dwellings:

Use any one of the following three alternates.

Alternate I. (Same as for Houses.)

Alternate II. Provide a 3-foot high crawl space—above finished grade—under the entire area of building. This crawl space to be permanently ventilated through fixed louvered openings in the enclosing walls and having sufficient area to provide 10 changes of air per hour. The crawl space shall have gas-tight floor construction at the top and an impervious floor slab at the bottom.

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[3] Casimir A. Rogus, "Use of Completed Sanitary Landfill Sites," in *1959 Yearbook*, (Chicago: American Public Works Association, 1959) p. 129-131.

Alternate III. If the structure is to have a basement or cellar, it shall conform with the following minimum requirements:

1. An approved continuous permanently gas-tight envelope shall enclose the entire outside face of the walls and the underside portion of the basement slab.
2. All pipes, ducts, and conduits piercing this protective envelope shall be equipped with gas-tight gaskets of an approved permanent nature.
3. Provide, above grade, fixed louvered openings through the outside basement walls so as to permit at least 10 changes of air per hour.
4. Install around the perimeter of the building a continuous trench, 3 feet wide by 3 feet deep, filled with gravel or similar other approved porous material.

Industrial and Commercial Buildings:

The superstructure construction shall comply with that specified for either Alternate II or III above.

Where undecomposed or partially decomposed putrescibles are exposed, as in the construction of basements and trenches, putrefaction and release of odorous gases take place. The use of an oxidizing agent to control odors may be required.

Bearing Values. Dynamic and static field tests on a refuse fill with an average in-place life of four years and an average compacted depth of 20 feet on top of a 10- to 15-foot layer of weak, compressible organic silt and meadow mat developed the following findings:

Dynamic Loadings: Freshly placed, compacted refuse will support repeated loadings of large rubber-tired equipment in excess of 25,000 pounds per tire. This supporting value is somewhat lower for older refuse fills, particularly when uncovered and wet.

Static Loadings: Well seasoned refuse fills placed in wet areas will support uniform loads of about 2,500 pounds per square foot if subjected to an equivalent preload for at least one year. Heavier loadings may require special foundation designs; each fill should be studied individually.

Air Fields

Landfill sites used for landing strips for aircraft must be well compacted and able to support, without excessive surface deflection, the wheel loads of the largest aircraft that will use the strip. A well compacted final cover two feet thick should be adequate for a light plane strip; however, additional cover may be required if large commercial planes use the field. As with parking lots built on completed landfills, paving for landing strips should be flexible.

LaGuardia Airport in New York was built on a landfill; and in Meriden, Connecticut, a runway at the municipal airport was extended over land reclaimed by landfilling. In Morgantown, West Virginia, where land reclaimed by landfilling was used for a landing strip, the entire fill operation was conducted with a crawler tractor. Tests made after compaction showed no appreciable settlement. A load equivalent to 65.9 pounds per square inch, the equivalent of the load of the main wheel of a DC-4, was applied to the fill and settlement was negligible.

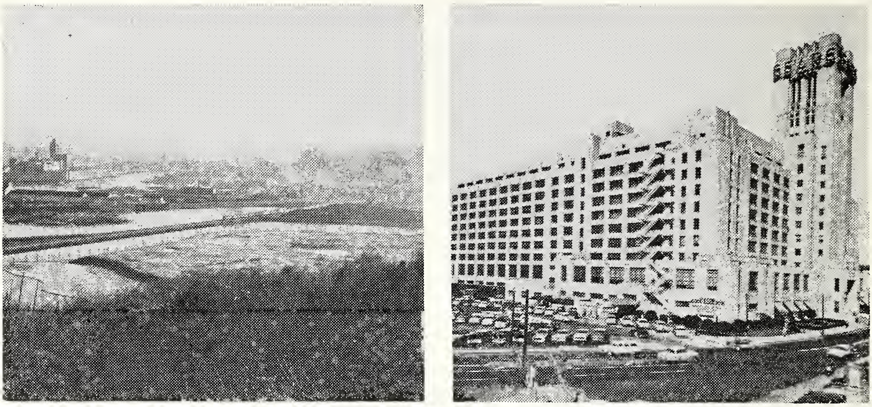


Fig. 54. Seattle is reclaiming tidal areas by using them for sanitary landfill sites; and Memphis has used completed fill sites for a department store.

Agriculture

The degree of stability and depth of final cover for a completed landfill used for agricultural purposes depend largely on the kind of agricultural use. Settlement is relatively unimportant if a stockyard is to be built; two feet or less of compacted cover is adequate. If crops are to be grown on the completed fill, settlement is important if it affects irrigation channel grades; and final soil cover must be sufficiently deep and of suitable material for growing crops. Surface drainage channels should be paved or stabilized to prevent erosion and fill leaching. The possibility of ground water pollution from leaching by irrigation water must be evaluated before a decision is made to use a fill site for growing irrigated crops.

In Kearney, Nebraska, reclaimed gravel pits are being used as sites for raising alfalfa, with two feet of final cover sufficient. The British make liberal use of land reclaimed by landfilling for agricultural purposes.

Landfills in Small Towns

With good planning and efficient operation, small towns of 5,000 and less population can operate sanitary landfills effectively and economically.

On such small projects, a tractor is needed only two or three hours a day (or, for that matter, on alternating days if there is alternate-day collection of refuse), so the tractor can also be used for other municipal projects—gravel loading, snow removal, and street excavations, for instance.

It has frequently been suggested that light equipment, costing well under $10,000, can be used to operate a landfill in a small town. Field demonstrations show that light equipment can be used with reasonable satisfaction for compacting and covering household and light commercial refuse in a site excavated with heavy equipment.

The United States Public Health Service conducted a research project in Chandler, Arizona, in 1954 in which two tractors were used: one of class 1, 20 to 25 drawbar horsepower and 2 to 3 tons total weight; the other of class 3, 30 to 40 drawbar horsepower and 4 to 8 tons total weight. Based on the field studies in Chandler, the Public Health Service reported:

1. Spreading and compacting refuse in a sanitary landfill for either a large or small city requires rugged equipment that can withstand the torques developed on the tractor frame when the tractor runs over large, solid objects that are present in refuse from a city of any size. Durability and dependability of a tractor, as well as the purchase price and economy of operation, must be considered when a tractor is to be used for landfills.
2. The class 3 tractor, equipped with an ordinary bulldozer blade, adequately and economically did in a 30-hour week all of the work that must be done with a tractor on a landfill operation for a city producing 69 tons of refuse weekly. It appears, therefore, that 100 tons of refuse can be handled by a class 3 tractor in a 44-hour week, and considerably more in areas where soils are light and easy to excavate.
3. The class 3 tractor used in this study was dependable and durable and operation costs compared favorably with those for heavy equipment used on large landfill projects.
4. The class 1 tractor is not sturdy enough for all kinds of landfill operations. It may be suitable for small towns in which soils are light and easy to excavate. It has been used satisfactorily for fill operations on sites that were first excavated by heavier equipment and at fills for household and light commercial refuse only.
5. Operating costs for a class 1 tractor, when it was the only piece of

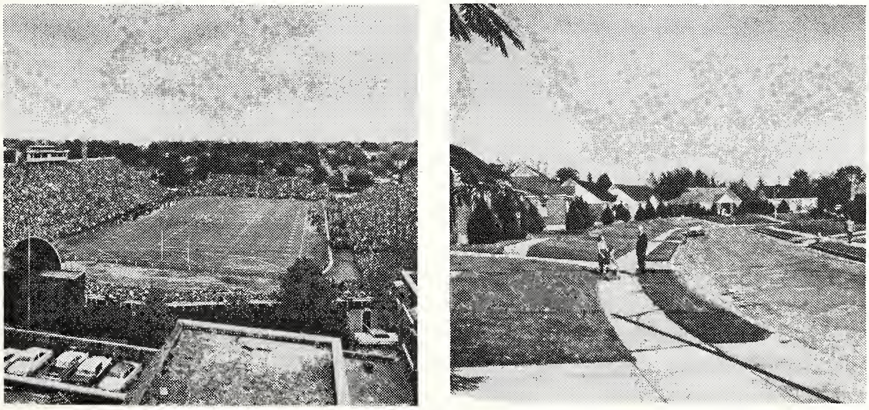


Fig. 55. Landfill sites in Memphis have been used for a stadium and for housing.

mechanical equipment used to operate a sanitary landfill, were excessive because the rate of disposal was low and repair costs high.

6. A reconditioned, factory guaranteed class 3 tractor purchased for about the same amount as a new class 1 tractor performs on small town landfills more satisfactorily and economically than a lighter, less durable new tractor in class 1.
7. Tests of class 2 tractors and others in class 1 are necessary before even broad conclusions can be drawn on what the most economical tractor is for small landfills.
8. Small cities initiating a landfill program should make a cautious approach to the kinds of refuse it accepts for the fill; operations can be modified as the work progresses and as operators learn the techniques that fit the needs of the town.

Trenching

Small towns can modify the landfill operation by using a form of sanitary trenching. Often the city dump can be used as the site, although it is usually necessary to clean up the dump before excavating a trench. It may be necessary to rent heavy equipment to move the rubbish accumulated on the site and to excavate trenches. If heavy equipment cannot be obtained, an ordinary farm tractor and a small, front-end loading bucket or bulldozer blade can be used after large items such a tree limbs, car fenders, and barrels have been removed. A separate dumping trench or area may be designated for large objects. Although it is not possible to control fires in trenches in this modified fill, a program of burning household refuse is not recommended.

A simple program of sanitary trenching for a small town might follow these steps:

1. Tell the townspeople what you are doing, why, and how.
2. Clean up the old dump and build an all-weather road to the site, renting heavy equipment if necessary.
3. Dig a trench, store dirt at ends or on sides, and designate an area for large objects.
4. Compact and cover the refuse in the trench at least twice a week in warm weather and as often as practical in the winter. Cover the top and face with at least 2 feet of dirt.
5. Each spring use heavy equipment to put into the fill large objects that must be disposed of separately. (Large bulky combustibles can be burned.)
6. Dig a new trench.

The program can be carried out by contract with private operators or by using municipal or county equipment.

Sanitary trenching, while less desirable than a sanitary landfill, is a vast improvement over the usual open town dump.

5 CENTRAL INCINERATION

Refuse incineration as it is known today is the process of reducing combustible wastes to inert residue by high-temperature burning. "Central incineration" means that the method is used by either a municipality or a private company to dispose of refuse at a plant to which refuse is brought.

It is a disposal method of recent origin. One of the earliest attempts to incinerate refuse was made in England in 1870. The first incinerator (or "crematory," as it was called) designed specifically for municipal use was built in 1874. Inasmuch as garbage was collected in swill form (wet) and the amount of dry combustible refuse collected with the garbage was extremely small, it was difficult to successfully operate early central incinerators. It was usually necessary to use auxiliary fuel.

The earliest English plants burned refuse at relatively low temperatures, producing a great deal of smoke and unpleasant odors. In 1885, an incinerator was designed that had a secondary fire in the main flue to consume the smoke and odors by assuring combustion at high temperatures. This method proved to be expensive, however, and it was found that acceptable results could be obtained by burning at higher temperatures in the furnaces themselves. Many of the incinerators utilized the waste heat. The low heat value of mixed refuse led to the adoption of a system called "separation-incineration" in which non-combustible material was removed from the refuse for salvage or open dump disposal, leaving only that that could be successfully burned. The first such plant was built in 1919, and most of the plants built in England since have been of the same type.

The first continental European incinerator was built in Germany in 1896. The European plants closely followed the essentials of the English type. A departure was the "Volund," developed in Denmark, which used a revolving, refractory-lined drum in the final burning stage.

The first incineration plant in the United States is said to have been built in 1885 for the Army installation at Governors Island, New York, although there is some evidence that incineration was used at other Army posts before 1885.

Allegheny, Pennsylvania, first used an incinerator in 1885; Pittsburgh and Des Moines in 1887; Yonkers, New York, and Elwood, Indiana, in 1893; and Washington, D. C., in 1896. These early incinerators were of a variety of sizes, shapes, and characteristics. To get the high temperatures necessary to reduce odors and smoke, some used auxiliary fuel and others partly dried the refuse before burning. After 1900, use of incinerators in the United States increased rapidly, and the modern incinerator furnace was developed. The first Decarie furnace was installed in the United States in 1901. It had a water-cooled basket for pre-drying wet garbage, water-jacketed walls, and it produced steam to drive forced draft fans and other appurtenances. Dumping grates and an ash pit were also innovations of this incinerator.

New York City built two rubbish incinerators in Manhattan in 1903 and four garbage incinerators in Queens in 1906. (It was customary to separate rubbish, garbage, and ashes at that time.) The major argument in favor of incineration of rubbish then was that the waste heat from the incinerators could be used as a source of power. But rubbish burning was subsequently abandoned because of operating difficulties and because production of waste heat was undependable. Incineration of garbage, although initially frowned on, was successful when coal was added to the incinerators at the rate of one pound of coal to eight pounds of garbage.

During the early 1900's the Heenan and Froude and Sterling furnaces were introduced into America from England, establishing incinerator practices that were followed successfully for many years in the United States. The furnaces were built on the principles of mutual assistance, air cooled castings, mechanically operated charging gates, and the flat or suspended arch.

A mobile incinerator was built and tried in Des Moines in 1928; a similar unit had been tried earlier in England. Neither proved to be practical for municipal refuse disposal.

In 1929 Carl Ilving of Copenhagen, Denmark, obtained a United States patent on a circular furnace with a rotating hearth and central perforated cone. This general design, in improved form, was in common use in the United States in the 1940's and 1950's.

In recent years, incinerator design has been markedly influenced by the need for more efficient operation and lower costs. This has led to the development of continuous-feed and mechanical stoking, mechanically controlled overfire and underfire air, facilities for fly ash removal, systems for continuous quenching and discharge of incinerator residue, and the use of sectionally supported walls and hung arches with high quality refractory linings. These new developments have made possible installation of larger incinerators with a lower potential for creating nuisances and the advantage of lower operating costs.

Evaluating Incineration as a Disposal Method

The purpose of central incineration is to provide an economic, nuisance-free, sanitary method of disposing of refuse. Whether it is the right solution to the refuse disposal problems of a city must be determined after careful evaluation of its advantages and disadvantages as they apply to the city in question.

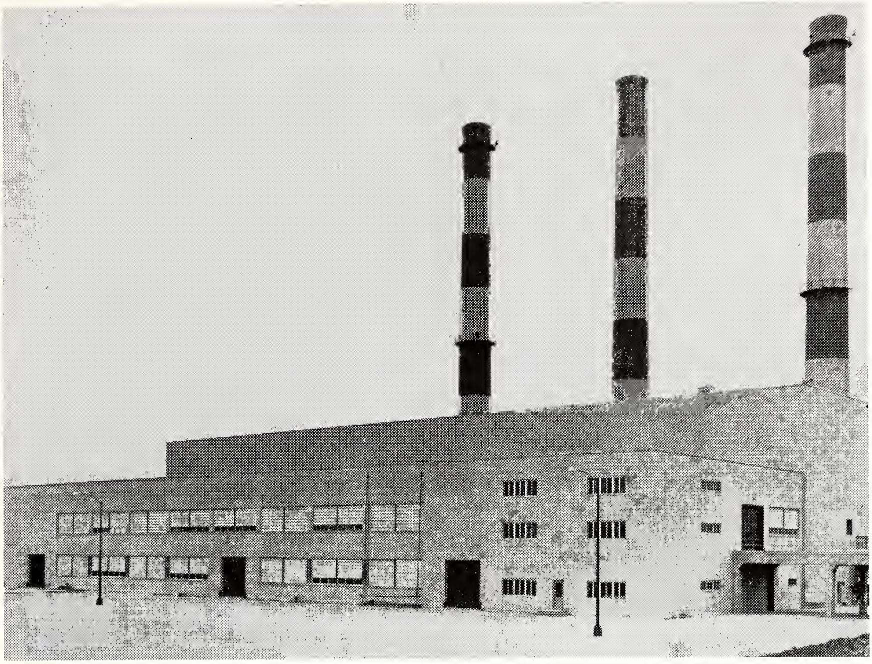


Fig. 56. The Calumet incinerator, Chicago, in which operations were begun in 1959, has six furnaces that have a total rated capacity for burning 1,200 tons of mixed refuse a day.

Advantages

The important advantages of central incineration are:

1. Much less land is required than for disposal in landfills. If there are insufficient sites available for landfills within economic haul distances, incineration may be the most economical method of disposal.
2. A central location for an incineration plant is possible. A carefully operated plant in a well-designed building that has well-landscaped grounds is acceptable in many neighborhoods, and so site selection is not as difficult as it is for some other disposal methods. A location near-central to tributary collection areas reduces hauling costs.
3. An incinerator can produce ash residue that contains a negligible amount of organic materials and thus is nuisance-free. The residue is also acceptable as fill material.
4. The modern incinerator can burn a good many kinds of refuse. It can efficiently burn combustibles to ash and can even reduce the bulk of the noncombustible components of mixed refuse. (It cannot handle objects that are very large, those that cause excessive smoke, and those that are explosive.)
5. An incinerator is not affected to any degree by climate or unusual weather.

6. Incinerators are flexible: they can be adjusted to handle increases and decreases in the amount of refuse. A plant operating 16 hours a day can be put on a 24-hour basis, for example, by modifying the actual hours of operation or by adjusting the degree and thoroughness of burning.
7. It is possible to get some income from incinerator operations. Waste heat can be used for steam or power; salvageable metals such as those in tin cans can frequently, under favorable conditions, be sold; and some cities that provide incinerator service to industry and business charge for it directly.

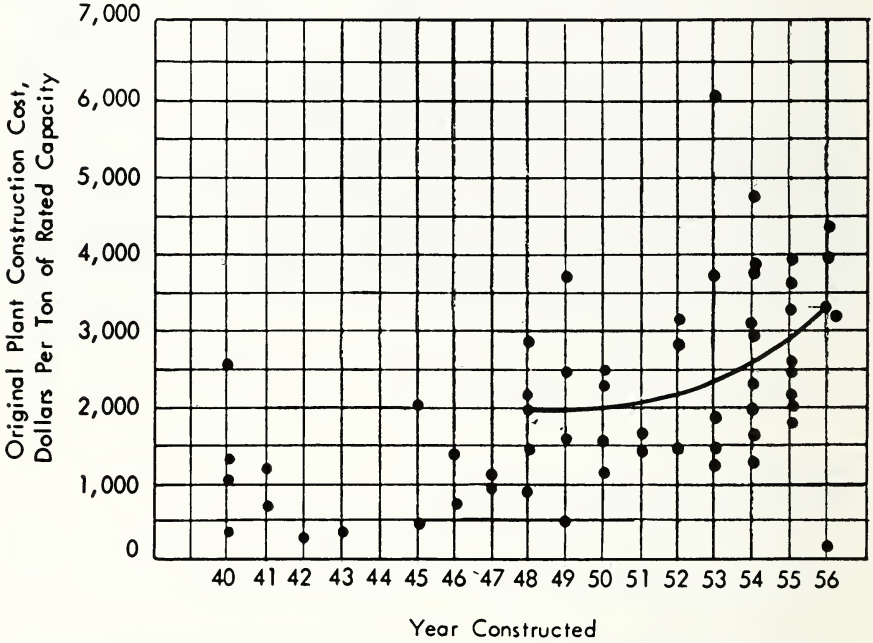


Fig 57. Original construction costs for 59 central incinerators built for municipalities between 1940 and 1956. Costs were computed on the basis of the number of tons of refuse an incinerator can burn in a day. The highest cost incinerator was built in 1953; the lowest in 1956. (Prepared by Solid Wastes Engineering Section, Committee on Sanitary Engineering Research, American Society of Civil Engineers.)

Disadvantages

The disadvantages of incineration must be weighed against the advantages, taking into account:

1. An incinerator requires a large capital investment. Construction costs vary from $1,500 to more than $6,000 a ton of rated 24-hour burning capacity. A plant serving 100,000 persons requires a capital invest-

ment of from $250,000 to $750,000, depending on the type of construction and equipment.

2. Operating costs are relatively high. Although the number of employees required to run an incineration plant may be less than it is for other methods of disposal, the wages for the skilled employees who operate, maintain, and repair an incinerator are higher than for men who work on a landfill, for instance. Maintenance and repairs costs may be high because of the high temperatures necessary for the burning and the dirty and damaging nature of the refuse and residue. Equipment and machinery are frequently damaged by wires; tramp metals; and fusible, abrasive, and explosive objects in the refuse. The combination of large capital investment, higher labor costs, and costly maintenance and repairs can produce a cost per ton for refuse disposal greater than for other acceptable methods.
3. It is sometimes difficult to get a site for an incineration plant because refuse disposal operations in any form are offensive to many people. Moreover, truck traffic to and from the plant may be considered a hazard and a nuisance, particularly in residential neighborhoods.
4. Incineration is not a complete disposal method. Ash and other residue from the burning process, including fly ash, must be disposed of by other means.

Costs

An incinerator plant must have refuse handling and storage facilities, furnaces and chambers where the refuse is burned, chimneys, facilities for handling the gaseous and solid products of the combustion process, and the buildings and grounds. The amounts and kinds of equipment and facilities in the plant vary widely, and, of course, the costs vary with them.

Construction

Most incinerator plants cost from $3,000 to $4,000 per ton of rated 24-hour capacity to build and equip. Buildings account for from 40 to 76 per cent of total costs (an average of 58 per cent); furnaces and appurtenances account for from 18 to 24 per cent of the total (the average 35 per cent); and the chimney accounts for from 4.5 to 11 per cent (the average 7 per cent).

Construction costs adjusted to 1957 levels reported for 21 incinerators built since 1949 (16 since 1954) had a median of $3,650 per ton of capacity. This compares to a median cost for 1946 of $2,000 a ton, or an increase of approximately 82 per cent in 11 years. General construction costs for the same period increased approximately 100 per cent. Construction costs for New York City incinerators are shown in Table 15.

TABLE 15

INCINERATOR CONSTRUCTION COSTS, BY FUNCTION, PER TON-DAY
NEW YORK CITY, 1959

Function	*Architectural and Structural*	*Mechanical*	*Electrical*	*Heating, Ventilation, Plumbing, and Misc.*	*Total*	*Per Cent of Total*
Delivery (tipping floor, scales, accessories)	$ 337	$ 4	$ 14	$ 18	$ 373	8
Handling (storage pit, cranes, hoppers, accessories)	658	141	14	27	840	17
Burning (furnaces, flues, chimneys, combustion chamber, accessories)	955	1,321	121	55	2,452	51
Residue removal (ash cellar, conveyers, controls, accessories)	309	108	66	41	524	11
Fly ash removal (settling chambers, screens, accessories)	113	15	9	9	146	3
Miscellaneous (utilities, grading, landscaping, demolition, furniture, tools)	313	127	30	16	486	10
Total costs	$2,685	$1,716	$254	$166	$4,821	100
Per cent distribution	55	36	5	4	100	

Refuse disposal services are usually paid for out of general taxes but construction of an incineration plant usually requires a bond issue to finance it. If capital costs are amortized over a 20-year period, the annual payments per $1,000 of total cost will range from $67.20 to $80.23 figured at interest rates varying from 3 per cent to 5 per cent.

Costs vary primarily because of:

1. Site preparation peculiarities and foundation conditions.
2. Special requirements of a city, including air pollution control equipment and aesthetics.
3. Geographical differences in costs of labor and materials.
4. The extent to which structures must be enclosed because of weather conditions and the need to control nuisances.
5. Special features, such as steam and power generation equipment, and the degree of automation used.
6. The operating schedule—the relationship between the number of hours of plant operation and the rated 24-hour capacity.
7. Provisions for expansion included in original buildings.
8. The extent to which costlier equipment and materials are used for the purpose of reducing maintenance and repair costs.

The increased use of automatic and semi-automatic labor saving devices, while raising initial costs, also reduces operating costs and in some cases brings additional economies by saving space.

Operation

Operating costs also vary widely, depending on the type of refuse burned and the thoroughness of the burning; the degree of sanitation controls exercised; the type of incinerator plant and extent of its mechanization; the wage scale and amount of fringe benefits; and the productivity of labor and efficiency of management. Operating costs for six cities

TABLE 16

OPERATING COSTS FOR MUNICIPAL INCINERATORS IN SIX UNITED STATES CITIES[1]

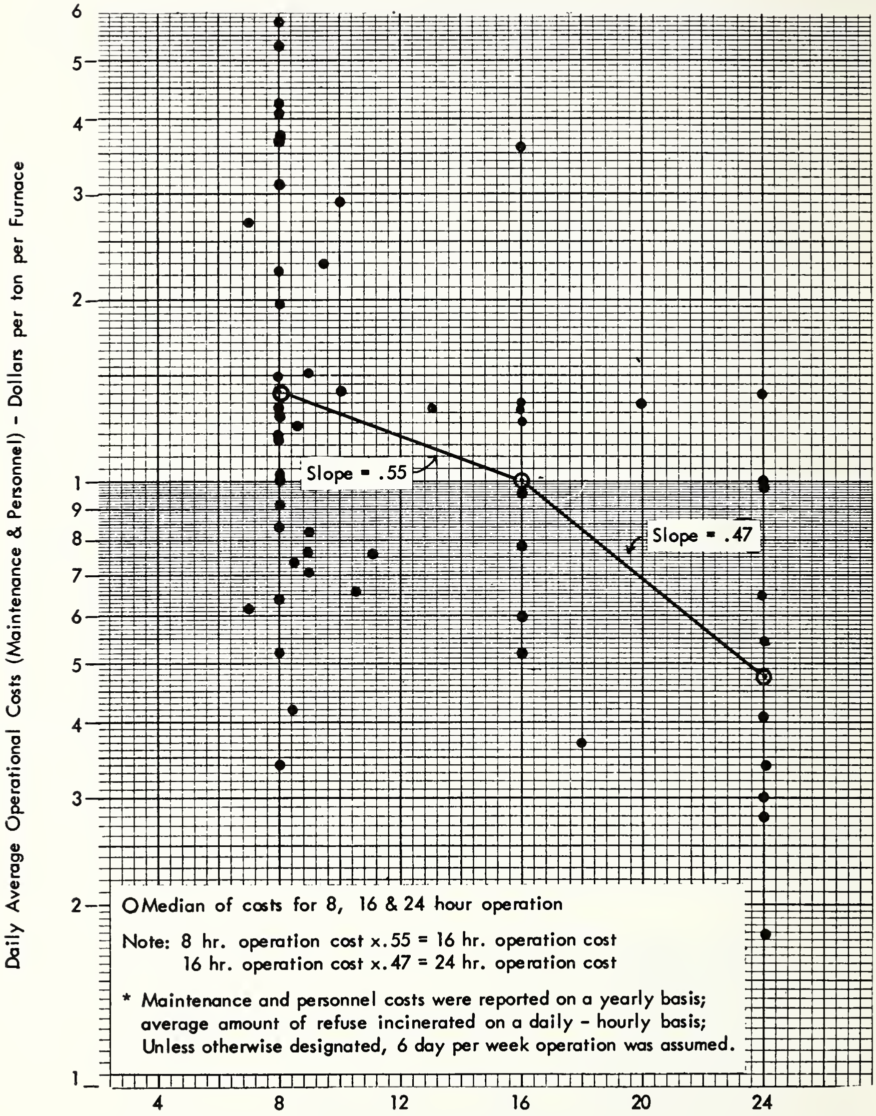
(Per ton of refuse processed)

Philadelphia	$4.24
Washington, D. C.[2]	2.28
Detroit	4.30
Milwaukee	6.49
New York City[3]	5.55
Los Angeles	3.13

[1] Costs are for one plant in each city in 1959 except New York, where figures are for 1958 for an average for three plants.

[2] Does not include amortization costs.

[3] Cost computed on basis of tons burned (amount charged minus residue).



○ Median of costs for 8, 16 & 24 hour operation

Note: 8 hr. operation cost x.55 = 16 hr. operation cost
16 hr. operation cost x.47 = 24 hr. operation cost

* Maintenance and personnel costs were reported on a yearly basis; average amount of refuse incinerated on a daily - hourly basis; Unless otherwise designated, 6 day per week operation was assumed.

Fig. 58. Effect of one, two, and three shifts on over-all costs for maintenance and personnel in incineration plants in 61 cities in 1956. Average costs for one shift, or eight hours of operation, were the highest; those for three shifts, or 24 hours of operation, the lowest. Figures at left start with 10 cents at the bottom; figures across bottom are for hours of operation. (Prepared by Solid Wastes Engineering Section, Committee on Sanitary Engineering Research, American Society of Civil Engineers.)

are given in Table 16; construction and operating costs for two types of incinerators are compared in Table 17.

In computing and comparing operating costs, it is important to recognize these factors and also to make sure that all of the costs—direct and indirect—are included. Costs must be accurately compiled and correctly analyzed if reliable comparisons are to be made. These factors and typical operating costs are discussed in Chapter 11, Refuse Disposal Management.

TABLE 17

COMPARATIVE COSTS OF TWO TYPES OF INCINERATORS, NEW YORK CITY

(In terms of 1958 costs)

	Mechanized Continuous Type (Average for 3)	*Manually Stoked Batch Type (Average for 4)*
Total construction costs per ton per day of capacity (including engineering but exclusive of land)	$5.500.00[1]	$3,750.00
Total operating costs per ton of refuse destroyed	5.55	7.50
Operating less residue disposal	2.40	4.20
Maintenance and repair	1.05	1.05
Administration and supervision	.50	.65
Pension	.60	.90
Fuel and utilities	.05	.05
Amortization	.95	.95

[1] Two plants since constructed elsewhere for $3,600 per ton per day.

DETERMINING PLANT LOCATION AND SIZE

Once the decision to use the incineration method of refuse disposal is made, it is necessary to decide where the plant will be located and what its capacity should be.

Location

Selecting a site involves both engineering problems and public acceptance of the location—and public acceptance is often the more difficult.

Engineering considerations include facility of construction and operation at as low costs as possible without creating nuisances for neighbors.

A central location usually cuts refuse collection costs, but the length of the haul to dispose of incinerator residue, although not a major consideration, is also a factor. If some salvageable materials are to be reclaimed, the distance to the nearest shipping point may be a factor. Topography and subsurface soil conditions may also affect costs. For instance, a hillside site may reduce construction costs because access to the tipping floor can perhaps be more cheaply built than if it were a flat site. Similarly, the type of foundations required and the character of subsurface ground waters may have a profound effect on construction costs.

In large urban areas the site problem is usually difficult. To avoid long hauls for collection trucks, a central location is often best, but if the site is near a residential neighborhood it is almost certain that nearby residents will object because they fear nuisances from smoke, fly ash, noise, odors, and heavy traffic. Neighbors also sometimes fear that the plant will deflate real estate values, which may be justified, depending on the type of neighborhood and the route the collection trucks must take to the plant. Furthermore, neighbors often fear that the plant will look like a factory. And although a good architect can design a good looking exterior, the chimney may convince residents that it does look like a factory. If that is true, stub-type chimneys with forced draft may have to be used. In any event, the zoning ordinance probably will prohibit an incineration plant in some areas of a city.

Sites are sometimes available in large cities in an industrial or semi-industrial area, where concern about nuisances, real estate values, and truck traffic is not as great as it is in residential areas.

In small cities the problem can frequently be solved by selecting a site outside the populated area that at the same time does not increase hauling costs excessively.

Once a site has been decided upon, it is important to institute a program to give the public the facts on it. Public acceptance may be most difficult to get. But a calm, honest presentation of the facts and the reasons for selecting the site and evidence that a well designed building will be constructed help to overcome objections.

Size

In determining the size and number of incineration plants needed in a city, the following must be considered:

1. The amount and kinds of refuse to be burned.
2. Hours of operation contemplated.
3. Seasonal peak loads and stand-by requirements.

Amount and Type of Refuse. The nature of the refuse (moisture content, combustible content, and weight) affects the size of the incinerator needed, as does the amount of refuse produced in a city. How to determine refuse quantities and kinds is discussed in Chapter 2, Quantities and Composition of Refuse.

Hours of Operation. Most incineration plants are operated for one, two, or three eight-hour shifts a day, and usually for five or six days a week.

Incineration plants in large cities are usually operated around the clock. If the amount of refuse that must be disposed of increases, plants are expanded or additional ones are built.

In small cities, the incinerator is often large enough to dispose of all refuse in eight hours a day. As the city grows, the plant can be put on a 16-hour or 24-hour basis to take care of increases in the amount of refuse. A plant designed for eight-hour-a-day operation requires almost three times the capacity of a plant designed for around-the-clock operation. Eight-hour-a-day plants are usually found only in small cities. They are often the direct-charge type or have only small storage pits that cannot hold more than an eight-hour collection of refuse.

Capital costs of an eight-hour plant may be more than twice the costs of one of similar size designed for 24-hour operation. Continuous operation of an incinerator permits more effective and efficient burning and creates fewer odor nuisances because the incinerator is not heated up and cooled down at the beginning and end of each shift. Damage to the refractory linings of the furnaces and chambers from thermal shock is also reduced.

There are cities—Miami, Louisville, and Atlanta, for instance—that operate incinerators seven days a week, mostly because they use recovered waste heat to heat nearby buildings.

Peak Load Requirements. Large incineration plants must have more than one furnace to meet the requirements of peak periods and for stand-by so that major repairs can be made without resorting to incomplete burning (toasting) of the refuse or shutting down the entire plant. It may be necessary during those times of the year when the most refuse is produced to use an incinerator at 100 to 110 per cent of its rated capacity. In off seasons it may be used at only 80 to 90 per cent capacity, which is the time to make repairs. Incinerators should not be built to the capacity of the peak refuse day, since much of the year part of the capacity is not used. It is important, therefore, that the capacity be a balance between the highest and lowest refuse collection periods.

Long-range plans should also be made to take care of increases in amounts of refuse in the future. If only one plant is contemplated, provisions for expansion of it should be included in the original plans for the plant. If more than one plant is contemplated, locations for additional ones should be considered in relation to the first one. It is advisable to project the peak load of refuse for at least 25 years, using the most reliable data available on population growth and changes in living habits of the residents of the city (see Chapter 3, Selecting Disposal Methods).

Facilities for Handling Refuse

Besides the furnaces and their auxiliaries, incineration plants must have other components for handling refuse, the kinds and amounts depending on the type and capacity of the plant.

Truck Scales

Scales for weighing refuse trucks and recording other information can be of the conventional mechanical type with manual operation. Or they can be of the more sophisticated type with load cell supports and electromechanical equipment that records information on the net load, kinds of refuse, points of origin and disposal of the refuse, truck and driver's identification, weighmaster's number, and the date and time the truck was weighed.

The latter type scales, which are not dependent on manual settings of tare-weights, have been found to be accurate, mechanically dependable, and tamperproof. Although costlier initially than manually operated scales, their aid to better management offsets the cost several times over. They may be particularly useful at incineration plants that serve several cities because costs can easily be allocated from the data automatically recorded.

Truck scales may or may not be inside the incineration building. They should, however, be near the point of entry to the tipping floor and provisions should be made to prevent trucks from by-passing them. There should be good visibility of the trucks and tipping floor from the scale house, and truck drivers and weighmaster should be able to talk with each other easily.

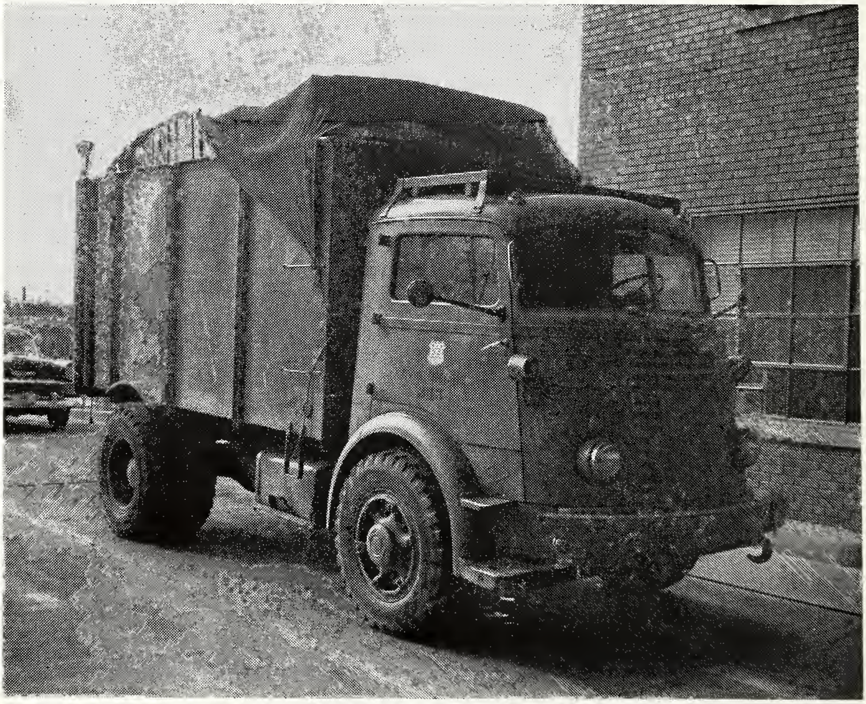


Fig. 59. It is necessary to know the weight of the refuse disposed of in incinerators if a plant is to be operated efficiently. This truckload of rubbish is being weighed before driving onto the tipping floor of the Mt. Olivet incineration plant in Washington, D. C.

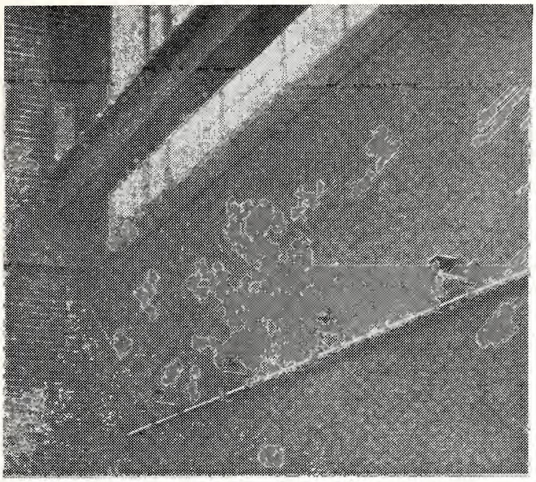


Fig. 60. A water spray system similar to this one in the Brookline, Massachusetts, incineration plant is often used to settle dust and suppress odors after refuse is dumped into the storage pit. The water spray system can also be used to control the temperature of the furnace, which may rise too high when highly combustible refuse is burned.

Tipping Floor

The tipping floor is a paved area on which trucks maneuver when they dump refuse into the storage pit or charge it into a furnace. The floor area should be big enough, especially if enclosed, to permit quick and easy maneuvering of the trucks; and it should extend along the entire length of the storage pit so that several trucks can unload at one time. It may be inside or outside the building, depending on climate, the amount of money available, and the kind of neighborhood in which the incineration plant is located.

Reinforced concrete floors with a highly impervious surface and good drainage are recommended for tipping floors to permit daily flushing to remove debris.

If the tipping floor is a full story above ground level, the space beneath it can be used—at only slight additional expense—for truck or material storage or for a maintenance shop, locker and shower rooms, offices, or assembly rooms. Ramps leading to and from this floor may be used, depending on the designers' decision as to what is most economical.

In direct-charge plants, sometimes used for small operations, the tipping floor is usually small and is located above the tops of the furnaces. Refuse is charged directly into the furnace from the trucks or by use of a small bulldozer that dumps the refuse into the furnace through an aperture in the floor. Sometimes small hoppers equipped with mechanically charging gates are set into the tipping floor—low enough to allow trucks to discharge refuse into the hoppers.

Storage Pits

If not all refuse collected in a day can be burned during the hours the incinerator is in operation, some of the refuse must be stored. The most

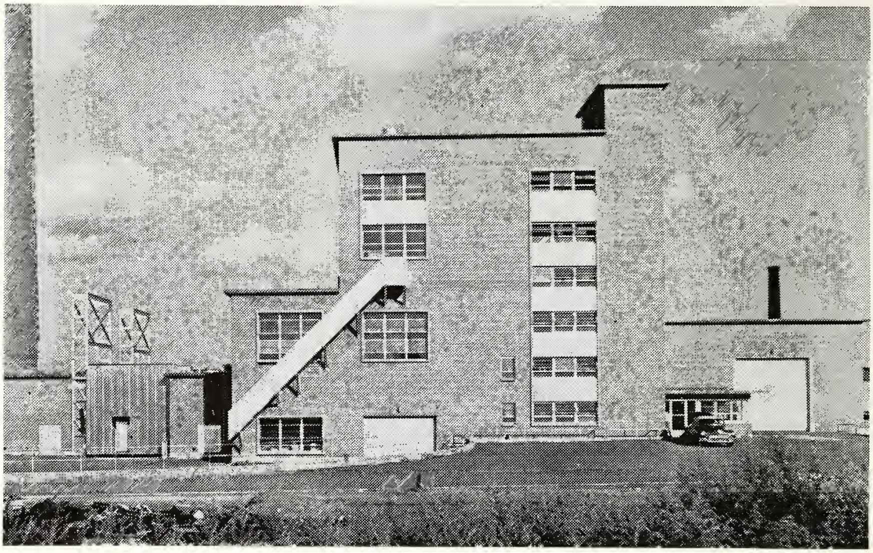


Fig. 61. Refuse that cannot or should not be put into incinerators, such as heavy iron, is put into this chute in the Rochester, New York, plant. The chute carries the refuse to ground level, and periodically a truck is backed up under the chute and the contents are removed and taken to a disposal site.

common storage place is a pit that is below the level of the tipping floor so that refuse can easily be dumped into it.

Storage pits are usually constructed of reinforced concrete as a safeguard against rodents and of sufficient strength to withstand both earth and ground water pressures. Surface armoring of light steel rails embedded in the concrete at intervals, rolled T-sections, or a continuous steel plate cover are frequently used to protect against damage by crane bucket corners and teeth. Sidewalls and the floor should have a dense, impervious finish to facilitate cleaning. The floor should be pitched toward drain troughs to simplify the cleaning process and to carry drainage to a dewatering sump pump.

The capacity of the pit may vary from 12 to 36 hours of incinerator burning capacity, depending on collection practices, hours of operation, and the amount of stand-by capacity of the plant.

In recent years there has been a considerable decrease in the density of refuse and a corresponding increase in volume, which in turn has increased the amount of storage space needed. The capacity of the pits in New York City incineration plants has increased with each new plant built—in 1961 they ranged from 65 per cent to 100 per cent of furnace capacity. Thus a 1,000-ton per 24-hour plant has a liquid level pit capacity of 1,000 tons, or 6,000 cubic yards for truck-compacted refuse.

Chicago's 720-ton per day Medill Avenue plant, which burns mixed refuse, has a pit capacity of approximately 1,000 tons and was designed on a 150-cubic foot per ton per 24-hour basis. Philadelphia's Northwest plant, which burns rubbish only, has a pit capacity of approximately 1,140 tons designed on a basis of a refuse density of 258 cubic feet per ton per 24 hours.

Even in the best managed incineration plant there are times when 24-hour operation is not sufficient to meet the demands, which may require that some of the refuse be held in the pit for as long as several days. Since putrefaction of refuse is rapid, especially in warm weather, storing refuse for several days can create strong odors. If odor-free operation is required, special attention must be given to ventilation of the storage pit so that negative pressure is maintained, making it impossible for odors to escape from the building, even when plant doors are open to receive collection trucks. This procedure has often been found impractical, however, and odors must be controlled with deodorants or chemical masking agents.

Charging Equipment

Several means are used to charge refuse into incinerators and each requires various equipment, including hoppers and charging gates and cranes and accessories. Skip loaders, oscillating conveyers, rams, and bulldozers also are sometimes used, although not frequently.

Hoppers. Charging hoppers are supposed to keep an even flow of refuse going into the furnaces. They are located above the top of the

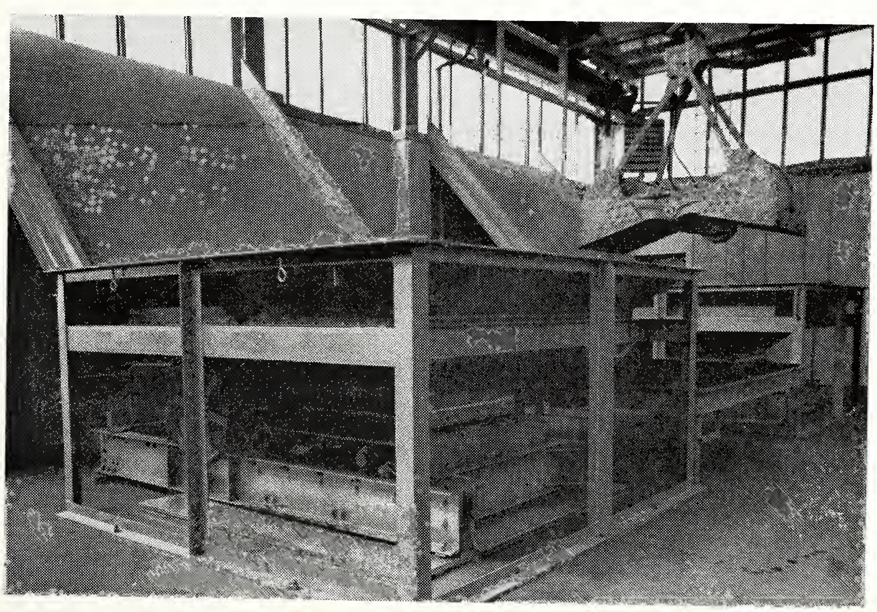


Fig. 62. Charging hoppers, hopper "splash" plates, and charging gate at the Belmont, Massachusetts, incineration plant.

furnace so that refuse can descend into them. The number of hoppers for each furnace varies with the number of cells; one hopper per cell is customary. Single cell rectangular or circular furnaces usually have a single charging hopper with a bottom opening of 25 to 35 square feet.

Batch-feed type furnaces require hinged sliding or rolling gates to permit refuse to be discharged from the hoppers into the furnaces and to close the opening at the top of the furnace. These are usually in an inverted steel box lined with refractory material and are manually or mechanically operated.

In continuous-feed incinerators the hopper discharges into the furnace through a rectangular chute in lieu of a gate. The chute is kept filled at all times to maintain an air seal.

In small furnaces (up to 100-ton capacity) refuse is often charged directly into the hoppers from collection trucks.

Cranes. In medium size incinerators (100- to 300-ton capacity) refuse is often raised from the storage pit to the charging hoppers by monorail cranes. And although a monorail crane limits the width of the storage pit and its performance, in some plants it is adequate and more economical than other types of cranes.

In large furnaces (more than 300-ton capacity), a bridge crane is essential to handle the large volumes of refuse and to permit a wide storage pit. The flexibility needed in charging and recasting the refuse, the high speeds necessary, and the strain to which a crane is put in a big plant can be met only by the bridge type. It should be built to the rugged specifications of mill-type cranes.

Cab control for bridge cranes is not essential but it is usually used because it offers better visibility and safer operation than stationary control. Dust and wide variations in temperatures make air conditioning in the crane cab essential. Stationary control, located at the center or in a corner of the storage pit, is standard with monorail type cranes but is used only occasionally for bridge cranes.

The size and number of cranes needed is geared to the size of the incineration plant. Stand-by cranes should be available because if even one of those needed for normal operation breaks down, the entire plant can be put out of operation.

The recommended maximum operating speeds for cranes that are safe in an average capacity incineration plant (300 to 600 tons) are 300 feet per minute for hoisting and trolley travel and 350 feet per minute for bridge travel. Full magnetic controls are desirable.

Many crane accessories are also needed. Grapples or buckets of the clamshell type with tines or teeth of good design and manufacture built of steel that will withstand a great deal of abrasion are necessary. Buckets that can open and close rapidly and that have lips so positioned and hinged that they can pick up a full bucketload of refuse with each bite are also required for efficient operation. Grapples and buckets ranging in capacity from 1 to 4 cubic yards are in general use in incineration plants. Larger

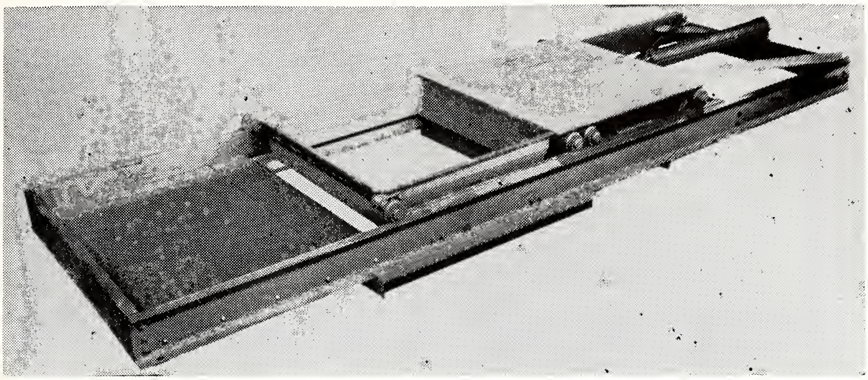


Fig. 63. This five-foot by five-foot charging gate (shown open) is used in the Jersey City incineration plant.

sizes, up to 1½ tons net load, are usually used with high capacity, continuous-feed furnaces. An automatic lubrication system for the crane is also desirable.

Combustion of Refuse

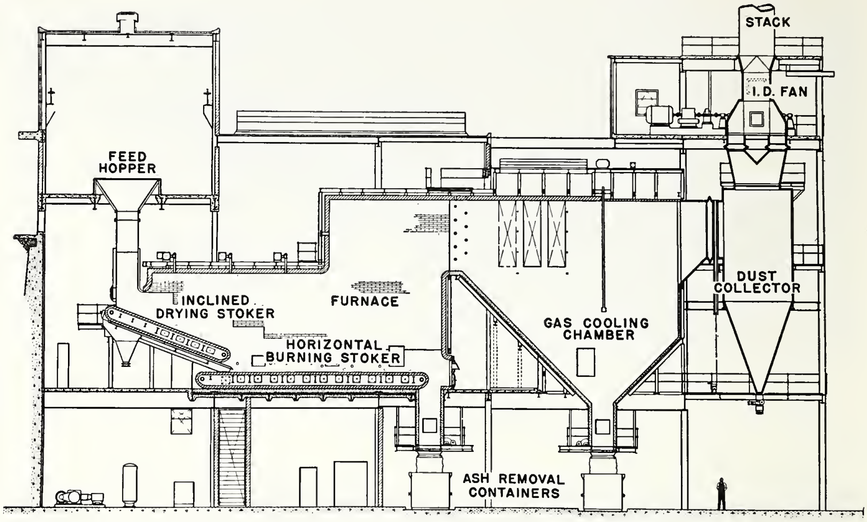
There is lack of agreement, even among incinerator experts, as to the correct words and terms for the equipment and structures used to burn refuse. For instance, some use "incinerator" and "furnace" synonymously (as does Noah Webster), while others consider the "furnace" only a part of the "incinerator"; some use "furnace" to include all burning apparatus and structures—drying hearth, grates, ignition chamber, combustion chamber, subsidence chamber, and breeching. Still others use "furnace" to mean only the main chamber in which the major burning takes place.

This confusion stems from the fact that the burning of refuse actually progresses through the steps of drying, igniting, burning of solid wastes, burning of gaseous wastes, and finally settling out of particulate matter before discharging the gaseous end products into the atmosphere through the chimney. Each of these steps overlaps in varying degrees, depending on the characteristics of the refuse burned and the operating methods used. The terms as they are used here—and the recommended definitions—are:

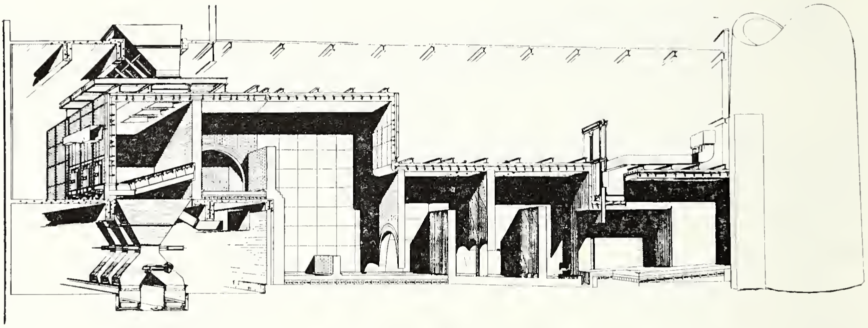
Incinerator—The entire plant (used for burning solid wastes), including refuse handling and storage facilities, furnaces, combustion chambers, subsidence chambers, residue handling and removal facilities, chimneys, and all auxiliaries.

Furnace—An enclosed, refractory lined structure equipped with grates and supplied with relatively large volumes of air, in which most of the burning takes place.

Combustion chamber—An enclosed, refractory-lined structure, some-


STACK
I. D. FAN
FEED HOPPER
DUST COLLECTOR
INCLINED DRYING STOKER
FURNACE
GAS COOLING CHAMBER
HORIZONTAL BURNING STOKER
ASH REMOVAL CONTAINERS

Figs. 64 and 65. Cross section drawings of one of the furnaces of the Calumet incineration plant in Chicago (top) and the Northwest plant in Philadelphia (bottom).



times combined with the furnace, in which the secondary, more complete burning of air-borne particles and gases takes place.

Subsidence chamber—A large, separate, insulated chamber in which exhaust gases are expanded and slowed down so as to settle out the particulate matter before the gases are discharged into the atmosphere.

Furnace

The furnace as considered here includes the ignition and primary combustion chambers, where preheating, drying, ignition, and most of the burning of refuse takes place. In the furnace are the hearth, the grates, the ash hopper and gate; stoking may be manual or mechanical. Several different types of furnaces are now in use, with the most common the following:

1. The single-chamber, cylindrical, batch-feed type. This is a refractory-lined furnace charged through a door in the upper part of the furnace. Refuse is dropped into the furnace periodically and stoked to the periphery manually or mechanically by a rotating cone with extended rabble arms. The dumping grates are located around the periphery and are operated whenever the accumulation of ash warrants removal.

2. The single- or multiple-cell rectangular, batch-feed type. This may be a refractory-lined or water-cooled furnace with a charging door in the middle or near the back of the ceiling of each cell. It is equipped with either fixed or moving grates set level or inclined.

3. The continuous-feed type. The major mechanical difference between this and the batch-feed types is obvious from the names: refuse is fed into one in batches; into the other continuously (ashes are also removed continuously and an air seal is maintained within the furnace continuously). The inclined, rotating-kiln type is essentially the same as the continuous-feed type except that it has a refractory-lined, slowly revolving cylindrical kiln that is used in the final burning stage.

In the continuous-feed types of furnaces the grates are of the traveling type, inclined, flat, or a combination; the furnaces require a minimum of manual stoking.

Usually all three types of furnaces are lined with refractories and

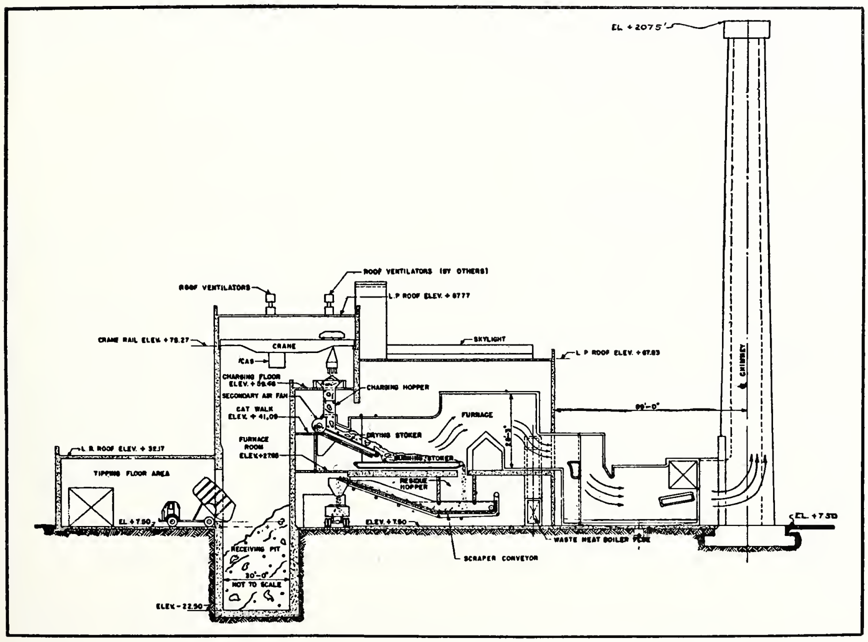

EL. + 2075'
ROOF VENTILATORS (BY OTHERS)
ROOF VENTILATORS
L.P ROOF ELEV. + 8777
CRANE RAIL ELEV. + 78.27
CRANE
SKYLIGHT
L. P ROOF ELEV. + 67.83
CAB
CHARGING FLOOR ELEV. + 59.46
CHARGING HOPPER
SECONDARY AIR FAN
CAT WALK ELEV. + 41.08
FURNACE
99'-0"
℄ CHIMNEY
DRYING STOKER
FURNACE ROOM ELEV.+27.88
L. R. ROOF ELEV. + 32.17
BURNING STOKER
TIPPING FLOOR AREA
RESIDUE HOPPER
EL. + 7.50
ELEV. + 7.50
EL. + 7.50
WASTE HEAT BOILER FLUE
RECEIVING PIT
SCRAPER CONVEYOR
30'-0"
NOT TO SCALE
ELEV. - 22.50

Fig. 66. A cross section of a modern continuous-feed type incineration plant. Note the differences in elevations of the tipping floor, the receiving pit, and the bridge crane.

insulating brick. Endless pipe coil linings for water cooling the walls are seldom used because of the loss of the residual heat of refractories.

Burning Rates. A furnace should operate at temperatures between 1,300° and 2,000° F., with an average of 1,700° to 1,800° F. If temperatures are kept to the minimum, practically all aldehydes, mercaptons, and other malodorous hydrocarbons will break down, thereby eliminating a source of air pollution. The maximum of 2,000° F. should not be exceeded because at higher temperatures refractories begin to deteriorate rapidly and the high gas velocities reduce the effectiveness of fly ash collection devices.

Furnaces designed to burn refuse follow the well established principles used in designing furnaces for burning such homogeneous solid fuels as sugar cane waste, bark, and wood. Experience with those fuels shows that the two major design elements are the grate areas and combustion volumes. For optimum burning, grate loads are based on a heat release from the burning material at the rate of 300,000 B.T.U. per hour per square foot. Combustion space is based on a heat release at the rate of 20,000 B.T.U. per hour per cubic foot.

Refuse, however, which varies in amounts of combustibles, moisture, density, and chemical composition, requires greater refinements and an analysis must be made of each situation. This is best shown in Table 18, which sums up the actual parameters used in the last decade in the design of refuse incinerators. The values shown are derived from a careful analysis of designs used for 24 large incinerators in 18 United States cities. Of these, 14 burn mixed refuse, 3 burn combustible rubbish only, and 7 burn combustibles only. The furnaces range in rated capacity from 90 to 250 tons per 24 hours of operation.

TABLE 18

PARAMETERS OF DESIGN FOR REFUSE FURNACES

	*Type of Refuse**	*Grate Loadings in Lbs. of Refuse per Hour of Operation per Square Foot of Grate Area*	*Volume in Cubic Feet per Ton of Refuse per 24 Hours*	
			Furnace (Primary) Chamber	*Combustion (Secondary) Chamber*
Range of Values	M	58 to 109	8.5 to 25.0	12.1 to 28.0
	R	50 to 72	13.4 to 14.5	26.6 to 31.8
	C	54 to 98	9.9 to 13.8	17.2 to 28.3
Average Values	M	77	12.7	18.5
	R	58	13.6	29.9
	C	77	11.5	21.3

*M—Mixed refuse made up of garbage, rubbish, and noncombustibles.
R—Refuse comprised of burnable rubbish only.
C—Refuse containing combustibles only, such as garbage and burnable rubbish.

The grate loadings used coincide reasonably well with the theoretical values of 75, 50, and 65 pounds of refuse per hour per square foot for the three types of refuse mentioned above. They correspond to a calculated heat release of 300,000 B.T.U. per hour per square foot. On the other hand, the total combustion volumes used coincide more closely with the theoretical values of 25, 45, and 35 cubic feet per 24 hours per ton of refuse for the three types of refuse. They correspond to a calculated heat release of about 12,500 B.T.U. per hour per cubic foot rather than the 20,000 advocated for the combustion of homogeneous fuels.

Although the actual ranges used for the separate primary and secondary combustion chambers vary disturbingly, the ranges for the total combustion space are reasonably close. This points up the need for a better distribution and allocation of combustion space between the two chambers. It might also be concluded that a single combined chamber large enough to release 12,500 B.T.U. per hour per cubic foot might be sufficient and more economical.

Designs based on such a broad rule of thumb formula of course must be checked in detail by thermodynamic calculations of heat and mass balances, air volumes and velocities, and operating temperatures.

Combustion Chamber

The combustion chamber as it is considered here is a secondary chamber in which more complete combustion of particulate carryover from the furnace and of volatile gases takes place. It may or may not be within the building that houses the furnace and it may or may not be combined with the primary combustion chamber in the furnace.

How the combustion chamber functions depends on the design and operation of the incineration plant. If the furnace (primary chamber) has sufficient volume so that gases have adequate detention time and the right amount of air is introduced at strategic locations to insure thorough mixing of the gaseous products of combustion, high temperatures will be maintained and practically all combustion will take place in the furnace. Under such conditions, an important function of the combustion chamber, in addition to completing the burning of gaseous and incandescent particulate matter, is to settle out the heavier large particles of fly ash. Gas velocities, therefore, should range from 10 to 40 feet per second.

On the other hand, if the volume within the furnace is insufficient and inadequate amounts of air are supplied, most of the secondary combustion of the particulates and gases will take place in the combustion chamber if sufficient oxygen is present.

Baffles, bridge walls, and similar means to force the gases into a circuitous path in the combustion chamber improve the mixing of gases and increase impingement of fly ash particles.

Because of the high temperatures maintained in the combustion chamber, it can conveniently be used for cremating dead animals.

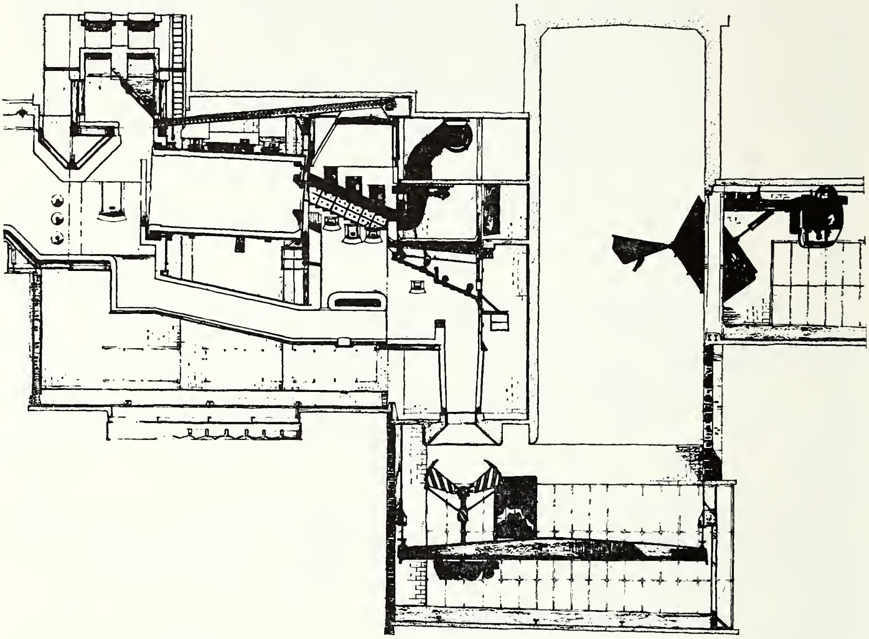


Fig. 67. The Volund rotating kiln incinerator is basically a continuous-feed incinerator, with mechanically reciprocating drying and ignition grates. The grates discharge the partly consumed and burning refuse into an inclined rotating kiln.

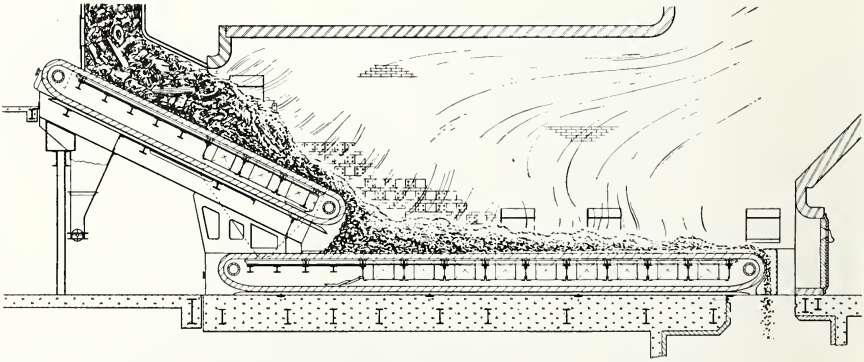


Fig. 68. A continuous-feed grate available commercially is the traveling grate made by Combustion Engineering.

Subsidence Chamber

The subsidence or settlement chamber is used primarily to complete the removal of fly ash and incidentally to complete the combustion of gases. Wet collectors, scrubbers, checkerwork refractory drop curtains, baffle walls, and other devices for removing particulate matter are used in addition to or sometimes in place of the chamber if a high degree of fly ash collection is required. The chamber is designed to keep gas velocities between 5 and 10 feet per second.

Where baffles or other configurations are used, low velocities at floor level are particularly important so that fly ash that settles there will not again be picked up in the gas stream. Wetting the baffles and floors has quite successfully prevented re-entrainment and promoted continuous discharge of settled particles.

Breechings

Breechings are high temperature ducts lined with refractory material that convey the hot products of combustion to the chimney. The cross-

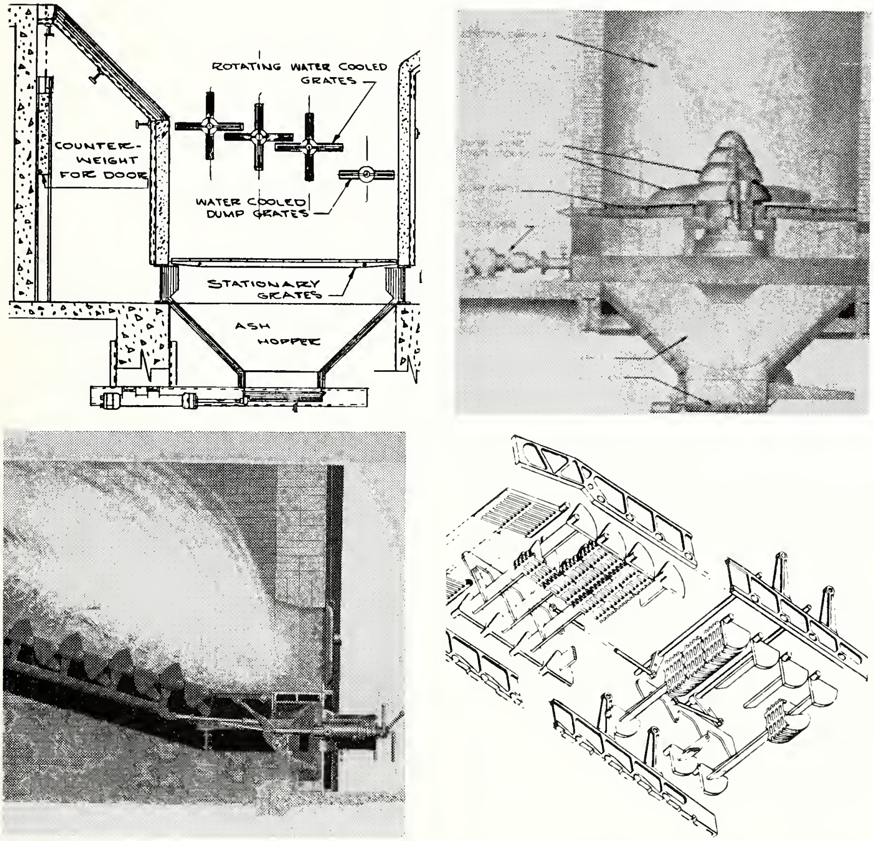


Fig. 69. Among the many automatic and semiautomatic grates used in batch-feed incinerators are the rotating water-cooled grates made by Aitrol Company, the conical shaped circular grates made by Mourse Boulger Destructor Company (top), the reciprocating grate made by Flynn-Emrich, and the rocker type stoker grate made by Nichols Engineering and Research Corporation (bottom).

section should be larger than that of the stacks. Gas velocities should be maintained at 20 to 40 feet per second.

Fly Ash Screens

Large particulate matter may be trapped by wire mesh screens that have openings of one-quarter inch or less, located in the breeching, in the stack, or even at the top of the stack. The preference, however, is for movable screens installed ahead of the stack, which reduces exposure to damaging high temperatures and at the same time provides good accessibility for cleaning and servicing. Double hung, counterbalanced construction permits putting one unit in the gas stream while the other is being cleaned and repaired. Stainless steel construction assures permanency and protection against rapid burn-out and corrosion.

Instrument Panel

The instrument panel is usually a large board of high dielectric strength on which all instruments that record draft, temperatures, and other data on operation and all switches and push buttons for operating the furnaces are mounted.

Air for Combustion

An adequate, correctly distributed supply of air is basic to the combustion process. Air for combustion is referred to as primary and secondary: the primary air is introduced under the grates; secondary air is introduced over the fire.

Primary Air. If all other factors are constant and within reasonable limits, the rate of flow of primary air through the fuel bed controls the rate of burning. The grate burning rates in municipal incinerators usually require the installation of forced air fans. Supplying adequate undergrate combustion air at the correct pressure to maintain burning rates is especially important during periods when wet refuse is charged, because compaction of the soggy material makes air penetration difficult. Stoking and spreading the refuse on the grate are particularly important. Doing so breaks up clotted refuse and clinkers, helps keep all parts of the grate covered to promote uniform burning and the grate from being burned, prevents fine ash and particulate matter from being stirred up, and promotes efficiency of the burning by furnishing continuous contact between the refuse and air. In traveling grate furnaces these problems can be circumvented further by compartmentation of underfire air.

The practice of preheating primary combustion air by heat exchange or intermixing with the combustion gas products has not been used extensively in recent years because refuse is drier and more highly combustible. As a matter of fact, control of furnace temperatures to keep them within refractory limits is now more frequently a serious problem than lack of preheated combustion air; preheated combustion air is only beneficial when very wet refuse is put into the furnace. Then it dessicates the wet material and helps keep furnace temperatures high enough to promote good ignition and combustion. Paradoxically, the need for preheated air develops mostly when it is least likely to be available from hot combustion gases. Under these conditions the use of auxiliary fuels, properly applied, may be helpful.

Secondary Air. The main purpose of secondary or overfire air is to supply the turbulence and oxygen necessary to promote complete combustion of the burnable gases, vapors, and particulates leaving the fuel bed. Under certain conditions it is also widely used for cooling. It is usually introduced into the furnace above the fuel bed, and may be most effective when brought close to the top of the burning refuse. Care must be used in introducing overfire air so that the carryover of particulates from the fuel bed is kept to a minimum.

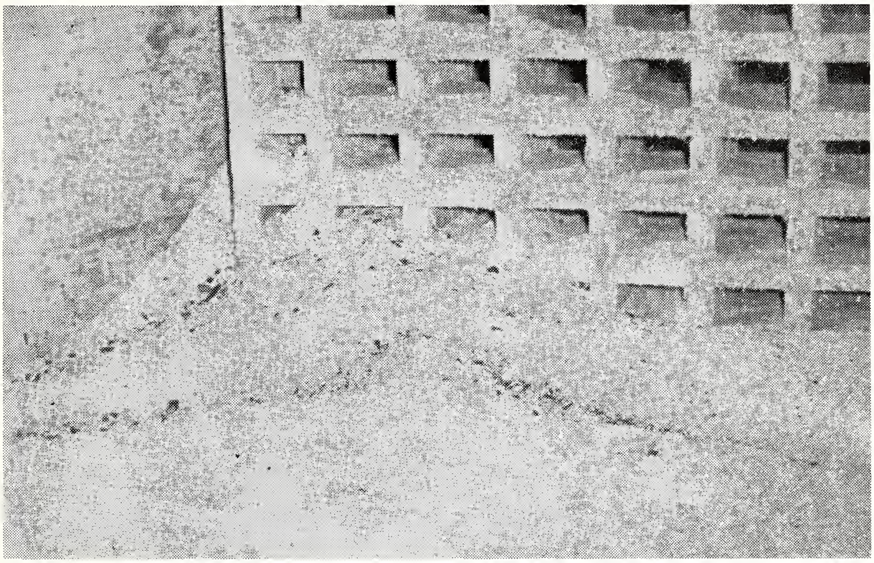


Fig. 70. This grid type fly ash baffle is used in the secondary chamber of the municipal incinerator in Rochester, New York.

The best design and placement of overfire air ports or nozzles must frequently be determined by trial and error.

Calculation of Air Requirements. Because of the heterogeneous nature of refuse collected in cities, it is difficult to calculate combustion air requirements. The importance of analyses of representative samples of wastes in the calculation process cannot be overemphasized. Table 19 gives the "theoretical" air needs for complete combustion of various kinds of refuse, including garbage. Previous studies indicate that most refuse that goes to municipal incinerators is cellulosic (moisture- and ash-free) and may be so considered in stoichiometric (theoretical complete chemical combinations) calculations of the incineration process.

Table 19

APPROXIMATE COMBUSTION CHARACTERISTICS OF VARIOUS KINDS OF MATERIALS AND AMOUNTS OF AIR NEEDED FOR COMBUSTION

Material	*High Heat Value[1] (B.T.U. per Lb. of MAF[2] Waste)*	*Air Needed for Complete Combustion (Lbs. per Lb. of MAF Waste[3])*
Paper	7,900	5.9
Wood	8,400	6.3
Leaves and grass	8,600	6.5
Rags, wool	8,900	6.7
Rags, cotton	7,200	5.4
Garbage	7,300	5.5
Rubber	12,500	9.4
Suet	16,200	12.1

[1] Values are necessarily approximate, since the ultimate composition of the combustible part of the materials varies, depending upon sources. The heating value of the material as it is received is obtained by multiplying the moisture-free and ash-free B.T.U. value of the materials by 1 − (% moisture + % ash)/100. For example, garbage with a MAF value of 7,300 and containing 35 per cent moisture and 5 per cent ash or other noncombustible material will have an "as-fired" heating value of 4,380 B.T.U. per pound.

[2] MAF means moisture-free and ash-free if ash refers to total noncombustible materials.

[3] These values are also approximate and are based on 0.75 pounds of air per 1,000 B.T.U. for complete combustion. For various percentages of excess air, multiply these values by (100 plus per cent of excess air)/100. For example, if paper is burned with 100 per cent excess air (5.9) 200/100 = 11.8 pounds of air per pound of moisture-free and ash-free paper will be required.

Enough air is required to completely convert all carbon, hydrogen, and sulfur in the fuel to carbon dioxide, water, and sulfur dioxide, respectively. Ignoring the sulfur content of fuel and assuming that most refuse is cellulosic, calculations show that 5.10 pounds of air are required for combustion for every pound of cellulose. Translating this for the average "as received" refuse and utilizing 200 per cent excess air generally used for best results, the air requirements amount to about 7.7 pounds of air per pound of refuse.

Air Fans and Ducts. Forced drafts for both burning and cooling are usually produced by a single motor-driven fan and are diverted to above or below the burning grate by a dampering system. If the system is entirely mechanical, modulating motors actuated by thermocouples are used. If more precise control of air is necessary, several fans can be used to provide air at various pressures and locations.

Dampers. The amount of draft in a furnace produced by natural draft stacks, and the diversion of hot gases through waste heat boilers can be controlled by dampers. They may be of water-cooled steel construction or of refractory and high-temperature resistant steel.

Auxiliary Burning

Because the percentage of garbage in refuse has decreased markedly in recent years, the need for auxiliary burners for incinerators has also decreased although during the seasons of the year when refuse has a high moisture content, they may be necessary. They may also be required to assist natural stack draft and to preheat refractories to reduce thermal shock at the time the furnaces are started. In any event, provision for auxiliary burning is usually considered essential for a municipal incineration plant.

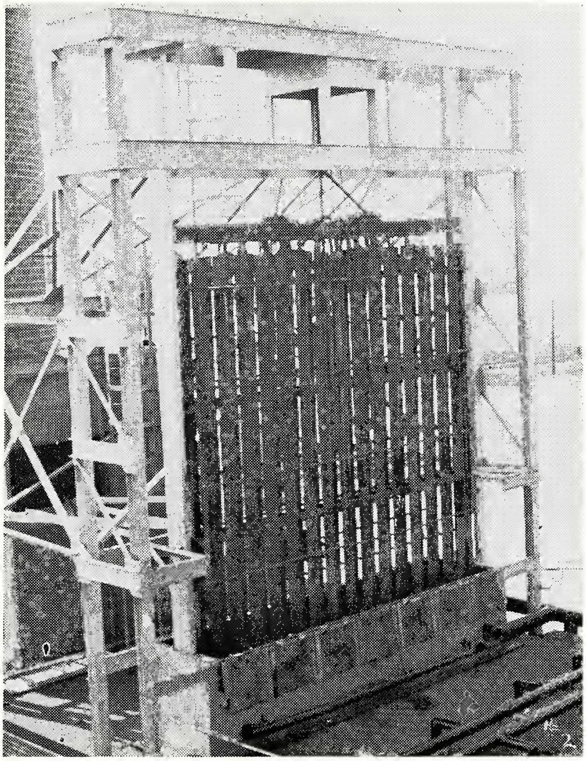


Fig. 71. Permanent scaffolding facilitates maintenance of baffle water spray system of fly ash removal. Baffles are in raised position; water pipes to spray nozzles are on the roof of the flue chamber (foreground).

If auxiliary fuel burners are used, they usually are located so that they furnish heat above the grate lines of the furnace for maximum drying of refuse, both by direct and radiant heat.

Oil, gas, wood, and coal have been used extensively as auxiliary fuels, although wood and coal are no longer common. If a municipal incinera-

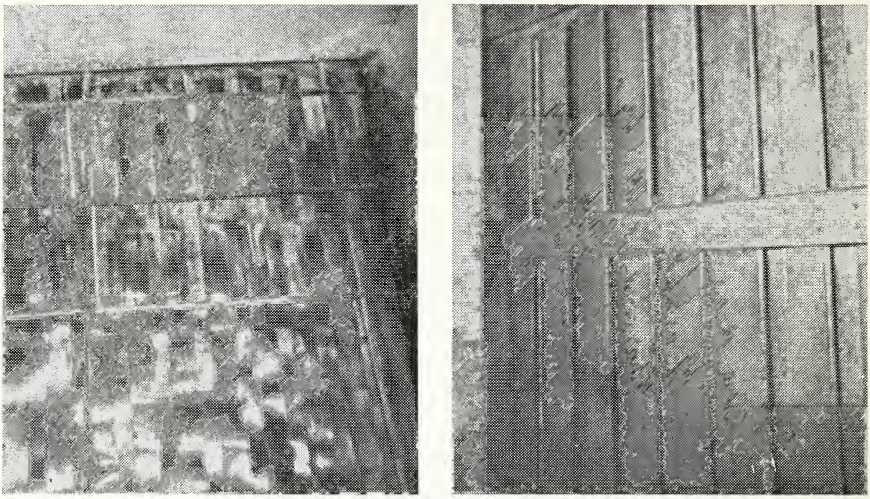


Fig. 72. Stainless steel baffle plates at left show the results of an incorrect water spray system. The inadequate spray applied to the steel plates did not reach the top of the baffle system. The 316 stainless steel channel type baffle plates at right have given satisfactory service in the incineration plant in Rochester, New York.

tion plant is near the sewage treatment plant, sewage digester gas can be used satisfactorily.

Auxiliary burners are customary in industrial incinerators, in both the furnace and the section between the furnace and the combustion chamber, because industrial wastes frequently contain materials that require special attention to eliminate odor and smoke. Auxiliary burning increases the high-temperature retention time and creates turbulence for more complete combustion.

Refractories

Refractories are comprised of various materials, such as fire clay, that are highly resistant to a great deal of heat. In incinerators they are used to line furnaces, combustion chambers, subsidence chambers, breechings, and chimneys because they protect the furnace and other parts of the incinerator against high temperatures and also serve as a reservoir of heat that equalizes internal temperatures.

Refractories can be produced from clay, silica, alumina diaspore, and other materials. Those produced from clay, sometimes known as fire clay bricks, are made in four grades: super-duty, high-duty, medium-duty, and low-duty. Insulating brick is made from the lower grades of fire clay.

Selection of Refractory Brick

The important factors to be considered in the selection of refractories for incinerators are cost; physical strength; resistance to heat, thermal

Table 20

TYPICAL PHYSICAL PROPERTIES OF REFRACTORIES[1]

Type	*Pyrometer Cone Equivalent*	*Density (Lbs. per Cu. Ft.)*	*Modulus of Rupture (Lbs. per Sq. In.)*	*Cold Crushing Strength (Lbs. per Sq. In.)*	*Thermal Conductivity (@ 1,800 B.T.U. per Hour per F.)*	*Thermal Expansion (@ 1,800° % Lineal)*	*Porosity (% Vol.)*	*Absorption (% by Wt.)*	*Resistance to Spalling*
Super-duty	33-34	140-145	700-850	1,200-2,400	10.6	0.64	10-18	4-7.5	Excellent
High-duty	31-33	140-144	800-1,000	2,100-2,800	10.6	0.64	12-19	5-8	Good
Intermediate-duty	29-31	136-140	1,100-1,400	4,000-5,500	10.3	0.64	13-16	6-7	Good
Low-duty	19-26	160-165	1,000-2,300	2,000-6,000	0.12	0.64	12-25		Fair
Insulating brick	17-32	40-46	60-320	115-380	3.0	0.50	22-26		Good
Alumina, 50%	34-35	130-135	700-1,000	1,400-2,000	10.1	0.60	27-34	10-12	Good
Alumina, 60%	35-37	130-140	850-1,150	2,100-2,500	10.1	0.60	29-36	12-17	to
Alumina, 70%	36-38	125-130	700-1,000	1,400-2,000	9.5	0.60	23-27	13-18	Excellent
Silica	31½-32½	103-107	600-1,200	1,500-3,000	12.4	1.3		13-16	Excellent above 1,200° F.; poor below
Silicon carbide	38	157	2,000		108.0	0.44	13.2		Excellent; slagging resistance excellent

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[1] Data, obtained from representative manufacturers' catalogs, determined through tests made according to recommendations of the American Society of Testing Materials.

and mechanical shock, spalling, slagging, and abrasive wear; low coefficient of expansion; and low bonding properties with respect to slag and clinker. To resist the deteriorating effects of heat, a refractory with a low and uniform coefficient of expansion, a minimum of fused glassy material, porous structure, and a high pyrometric cone equivalent will give the best results.

Surface abrasion in incinerators results when sharp objects in the refuse continuously rub against the lining of the furnace. Bricks of high physical strength with a hard, impervious surface offer the best resistance to such wear.

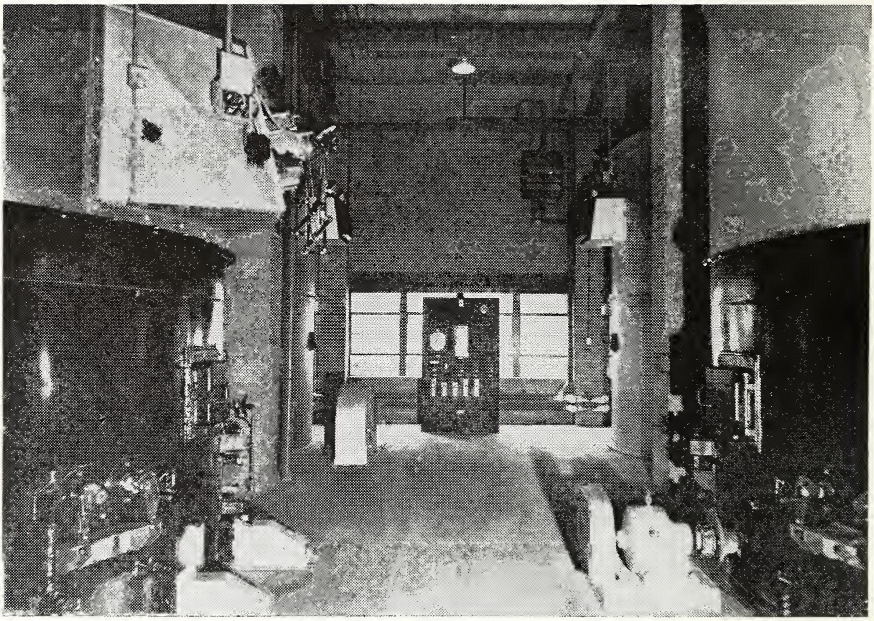


Fig. 73. The operating floor of an incineration plant must have the correct instruments and control aids for efficient operation, such as these at the Jersey City incineration plant.

Spalling occurs because of the differences in temperatures between the outer surface and the inner part of the brick, which, aided and abetted by moisture absorption and steam expansion, results in uneven expansion. To resist spalling, a dense brick with a fairly high pyrometric cone equivalent should be used.

Slag—a chemical flux of the oxides of sodium, potassium, iron, or calcium—forms on the surface of the incinerator lining, particularly when temperatures are high. It is deposited on and bonds itself to brick surfaces. As it accumulates, it reduces the volume of the furnace and eventually causes failure in the bricks because of its weight. The refractory material that best resists slagging has high density, low porosity, a

TABLE 21
SUGGESTED REFRACTORY PLACEMENT IN INCINERATORS

Incinerator Part	*Temperature Range (Degrees F.)*	*Abrasion*	*Slagging*	*Mechanical Shock*	*Spalling*	*Fly Ash Adherence*	*Recommended Refractory*
Charging gate	70-2,600	Severe Very important	Slight	Severe	Severe	None	Super-duty
Furnace walls, grate to 48 inches above	70-2,600	Severe	Severe Very important	Severe	Severe	None	Silicon carbide or super-duty
Furnace walls, upper portion	70-2,600	Slight	Severe	Moderate	Severe	None	Super-duty
Stoking doors	70-2,600	Severe Very important	Severe	Severe	Severe	None	Super-duty
Furnace ceiling	700-2,600	Slight	Moderate	Slight	Severe	Moderate	Super-duty
Flue to combustion chamber	1,200-2,600	Slight	Severe Very important	None	Moderate	Moderate	Silicon carbide or super-duty
Combustion chamber walls	1,200-2,600	Slight	Moderate	None	Moderate	Moderate	Super-duty or 1st quality
Combustion chamber ceiling	1,200-2,600	Slight	Moderate	None	Moderate	Moderate	Super-duty or 1st quality
Breeching walls	1,200-2,400	Slight	Slight	None	Moderate	Moderate	Super-duty or 1st quality
Breeching ceiling	1,200-2,400	Slight	Slight	None	Moderate	Moderate	Super-duty or 1st quality
Subsidence chamber walls	1,200-1,600	Slight	Slight	None	Slight	Moderate	Medium-duty or 1st quality
Subsidence chamber ceiling	1,200-1,600	Slight	Slight	None	Slight	Moderate	Medium-duty or 1st quality
Stack	500-1,000	Slight	None	None	Slight	Slight	Medium-duty or 1st quality

high melting point, and a chemical and mineral composition that does not bond or combine with slag.

Obviously, compromises must be made in the types of refractory used in various parts of an incinerator. The choice is different for different parts because the least costly material that will do the job efficiently should be used in each place.

Because silicon carbide has such a high melting point, low thermal expansion, high strength, low spalling loss, and chemical inertness, it may be used in almost any part of an incinerator. However, because of its high cost, it is usually used only in the most troublesome areas. For example, it may be economically used for 3 or 4 feet above the grates, where the greatest abrasive wear and slagging take place.

Insulating brick, which has low resistance to slag, abrasion, and mechanical abuse, should never be used in incinerators for the lining closest to the heat but only as backing for fire clay brick or other refractory material to control heat loss to the exterior. Its additional advantage is that it is lighter than common brick and therefore the supporting structures for it can be lighter.

Typical physical properties of commonly used refractory bricks are given in Table 20. Table 21 lists the conditions to which refractories are subjected in an incinerator and suggests the best quality refractory for each condition.

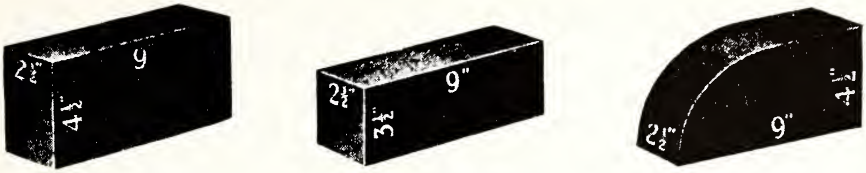
Costs. Costs of refractory bricks vary widely. For instance, in 1959, costs for a standard size brick (9 inches by 4½ inches by 2½ inches) ranged from about $2 each for silicon carbide to about 15 cents each for silica. The alumina bricks ranged from 35 cents to 25 cents, depending on the per cent of alumina; super-duty bricks through low-duty bricks ranged from about 18 cents each to 11 cents each; insulating brick cost about 19 cents each.

Plastic Refractories

The clays used in plastic refractories are similar to those in bricks. They are mixed, at the factory, with just enough water to form a stiff, workable mix and are shipped in either metal or waterproof paper containers. When installed, forms are used and the material is sliced, rammed into place, and trimmed smooth. However, instead of being burned in a kiln, as bricks are, plastic refractory develops its ceramic-like structure and bond by gradual, uniform heating up to a certain temperature after it is in the incinerator. Entire linings can be made of plastic refractories; with careful workmanship and correct heating procedures, good results can be obtained. However, at present plastics are usually used only for lining access, inspection and firing doors, for patching and shaping around curved openings, and to fill and line for other irregular surfaces.

Castable Refractories

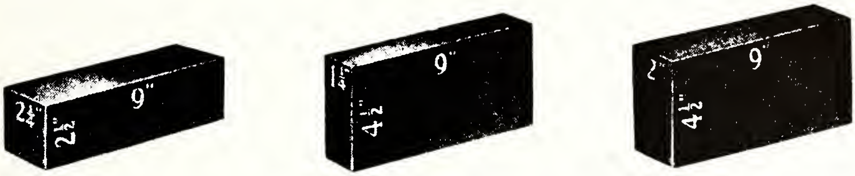
Castable refractories are also made of the same clays as those used in firebrick but with bonding additives to impart strength until the tem-



9" STRAIGHT
9"x4½"x2½"

SMALL 9" BRICK
9"x3½"x2½"

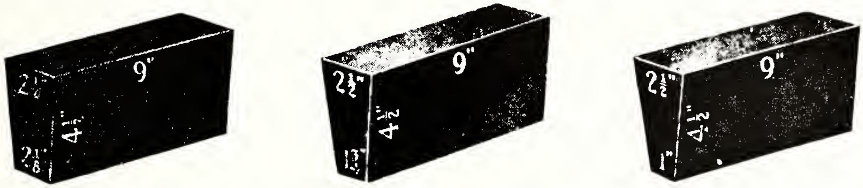
JAMB BRICK
9"x4½"x2½"



SOAP
9"x2½"x2¼"

SPLIT BRICK
9"x4½"x1¼"

2" BRICK
9"x4½"x2"



No. 1 ARCH
9"x4½"x(2½"-2⅛")

No. 2 ARCH
9"x4½"x(2½"-1¾")

No. 3 ARCH
9"x4½"x(2½"-1")

Fig 74. There are many shapes for firebrick; these are a few of the standard nine-inch series.

perature in the furnace is sufficiently high to develop a ceramic bond. They can be mixed and poured like concrete. Their use is still usually limited to door and charging gate linings, spot repairs and patching, and to special shapes.

Installation

Installation of a refractory lining is as important as the refractory itself. The details depend greatly on whether the wall construction is of the bearing or hung type and whether the roof construction is of the sprung arch or hung type. In any case, the most important factors are expansion and contraction. Firebrick expands in three directions when heated—vertically, horizontally along the plane of the wall, and at right angles to the wall. Vertical expansion is provided for by allowing room for upward movement; but horizontal expansion must be provided for by joints in corners or by expansion spaces in wall panels. All joints must be staggered and header or metal tie courses must be used to interlock the wall transversely. Methods for making and locating expansion joints vary; usually the joints are located at points at which there are radically different temperatures and where there is a major change in the structure configuration. While corner joints allow for differences in vertical expansion, they also sometimes weaken the structure; therefore, a joint is often put in the wall near the corner.

Mortar. The strength and durability of a self-supported refractory lining depend upon the kinds of bricks used, the manner in which they are laid, and the material for bonding them. The mortar materials should be as carefully selected as the brick with which they are used. There are two general kinds of mortars: air-setting and thermal-setting.

The most commonly used is the air-setting type, which hardens at room temperatures and in which some hardening takes place at any temperature.

Thermal-setting mortar forms a strong bond at temperatures between 1,400° and 2,500° F. This characteristic is a disadvantage because before temperatures reach 1,400°, a great deal of the soft mortar may have been eroded by gases passing over the lining. Furthermore, the brick is bonded only as deep as the high heat penetrates—sometimes not more than an inch.

Since firebrick linings must be laid with thin joints, the bricks should be dipped in a thin mortar; only when fitting or leveling is being done is it necessary to use a thick mortar and trowel.

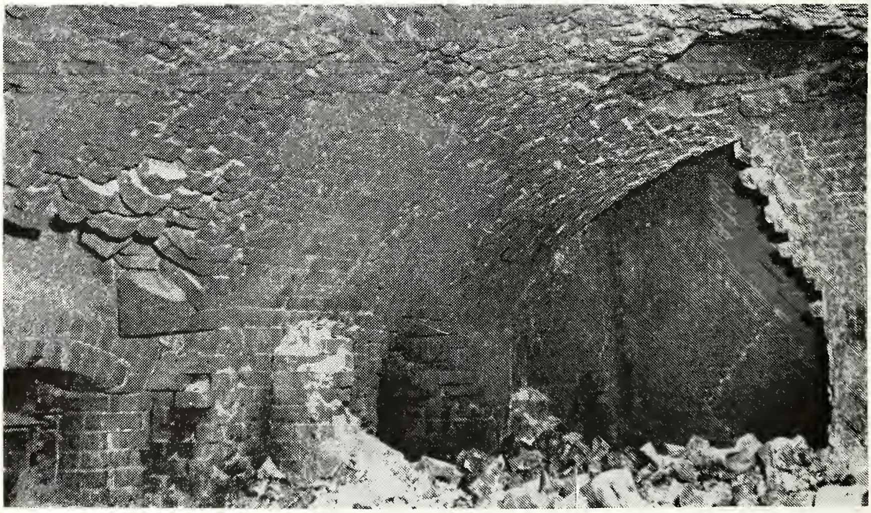


Fig. 75. The high temperatures produced when refuse containing relatively small amounts of garbage is burned can cause severe damage to refractories if the heat is not controlled.

Refractory Warm-Up

To "set" the brick construction and prevent damage to refractories and refractory mortar because of too rapid drying, too rapid expansion, and spalling it is essential that furnaces, chambers, stacks, and other parts of an incinerator be heated up to progressively higher temperatures for at least five consecutive days before they are used to burn refuse. Improper drying out can ruin the most carefully made and highest quality refractory linings.

Refuse should not be used as fuel during the drying out period. Instead, oil or coal salamanders, gas or oil burners, or waste lumber should be used, and temperatures should be carefully controlled.

The purposes of the drying out period are to drive out moisture from the refractory linings, accelerate bonding and cementing under controlled conditions, and permit gradual and uniform expansion. To do so, temperatures should be increased a few degrees each day. The temperature is usually kept below 150° F. for at least the first day. Thereafter the temperature is increased about 200 degrees every day or every other day until normal operating temperatures are reached and maintained for several days.

CHIMNEYS

A chimney or stack is an upright flue that conveys the gaseous products of combustion to the atmosphere and provides natural draft to assist combustion. When in operation, a chimney is filled with gases that have a higher average temperature than that of the surrounding air. As a result, the gases within are less dense than those of the outer air and the pressure at the bottom of the chimney is less inside than outside. This difference in pressure is the "draft" that can be produced in a chimney, and it is dependent upon height and temperature differential. The height and diameter of a chimney are determined by the amount of draft required, the velocity of the gases passing through it, and the maximum quantity of gas that must be dispersed. Drafts usually range in pressure from 2 to 4 inches of water and in gas velocities from 25 to 50 feet per second.

A trend toward short, stub-type stacks has developed because they reduce the hazards for aircraft and because they are not as detrimental to the value of adjoining properties as high chimneys are.

If low chimneys are used, draft must be provided by induced draft fans. The initial cost of the fans usually offsets the construction savings of the low stack, and operating and maintenance costs are substantial and continuous. Furthermore, even stub stacks must project at least 20 to 40 feet above projections on adjoining buildings to overcome the possibility of down drafts and the dangers of direct discharge of exhaust gases into the buildings.

With induced draft fans, drafts can be controlled, however—a significant advantage under certain atmospheric conditions and particularly in starting operations when natural draft stacks are only partially effective.

To avoid rapid deterioration of the fans, exhaust gases must be cooled to temperatures tolerated by metals used in the blowers by water sprays, cold air inflows, or both.

Several types of chimneys may be used for municipal incineration plants: steel, either guyed or self-supporting; masonry, made of either straight or radial bricks or blocks; and reinforced concrete.

Steel Chimneys

The advantages of steel chimneys are many: the initial cost may be lower, they are easily constructed, are lightweight in proportion to diameter and height, require less space than some other kinds, and they permit less infiltration of outside air than radial brick or tile chimneys do. The disadvantages are that they are unsightly, require guy wires for structural stability and wind resistance, maintenance costs are high, and they must be built of costly heat resisting alloys and must have special protective coatings to prevent rapid deterioration.

Steel chimneys can be made structurally self-supporting but because it costs more to do so and building code requirements for self-supporting chimneys are rigid, they are usually guyed with wires.

Masonry Chimneys

Masonry construction is most commonly used for high, natural draft chimneys because masonry chimneys can be designed to blend architecturally with the building; they do not require guy wires, brackets, or other ugly exterior reinforcements; they have a much longer useful life than those made of other materials; and maintenance costs are generally lower.

Because of their weight and great exposure to lateral wind forces, both the foundations and general design of masonry chimneys need special attention. They are usually made up of an outer structural shell and separate lining shell that can resist temperatures up to 1,000° F. The two shells are separated by an annular four-inch air space. The exterior shell, varying in thickness from 9 inches at the top to 20 inches or more at the bottom, depending on design, is built of special, wedge-shaped, perforated blocks of hard-burned refractory clay, usually colored to match the building brick.

Reinforced Concrete Chimneys

Chimneys made of concrete are inherently strong, and with properly designed reinforcements they can withstand much higher winds and greater earthquake stresses than other types can. Furthermore, a reinforced concrete chimney may be more economical than other kinds if the chimney is more than 200 feet high and 8 feet in inside diameter. The major disadvantage is that the surface may crack extensively from temperature and plastic stress conditions.

Linings

Steel stacks are usually protected on the inside with a relatively thin, bonded fused-glass lining. Masonry and concrete stacks as a rule are completely lined with firebrick (usually acid-resistant or first-quality) varying in thickness from 4½ inches at the top to 13½ inches at the bottom. The lowest 30 feet have in addition an extra 4½-inch thick renewable refractory lining of firebrick or castables known as a "target wall." Since linings do not affect the strength or stability of the chimney, they are ordinarily only sufficiently stable to support their own weight, and are separated from the outer shell by an annular air space. Some chimney builders fill this space with an insulating material; others leave it open so that circulating air can cool the chimney.

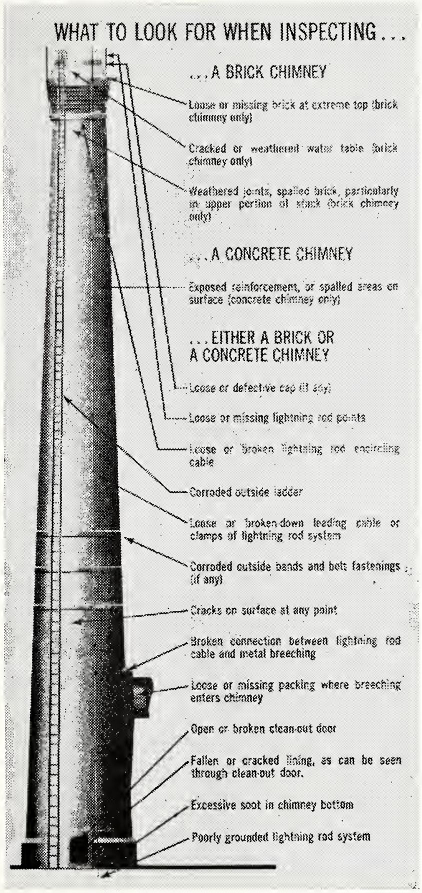

WHAT TO LOOK FOR WHEN INSPECTING . . .
. . . A BRICK CHIMNEY
Loose or missing brick at extreme top (brick chimney only)
Cracked or weathered water table (brick chimney only)
Weathered joints, spalled brick, particularly in upper portion of stack (brick chimney only)
. . . A CONCRETE CHIMNEY
Exposed reinforcement, or spalled areas on surface (concrete chimney only)
. . . EITHER A BRICK OR A CONCRETE CHIMNEY
Loose or defective cap (if any)
Loose or missing lightning rod points
Loose or broken lightning rod encircling cable
Corroded outside ladder
Loose or broken-down leading cable or clamps of lightning rod system
Corroded outside bands and bolt fastenings (if any)
Cracks on surface at any point
Broken connection between lightning rod cable and metal breeching
Loose or missing packing where breeching enters chimney
Open or broken clean-out door
Fallen or cracked lining, as can be seen through clean-out door.
Excessive soot in chimney bottom
Poorly grounded lightning rod system

Fig. 76. Periodic inspection of an incinerator chimney is important. Repairs require special skills and are almost always done on a contract basis.

Steel corset reinforcement of chimney linings to restrain "breathing" action under varying temperatures, to strengthen the chimney and reduce the deterioration of articulated masonry construction is now common. It is also important to provide expansion facilities between the chimney and the breeching and suitable insulation between the chimney and the structural footing.

Accessories

Accessories are necessary for every chimney: equipment to protect against lightning, aircraft warning lights, test openings, clean-out doors, ladders, catwalks, and caps.

Lightning protection is usually provided by ¾-inch lead covered copper rods projecting about 6 feet above the chimney cap and spaced about 8 feet apart. They should be rigidly fastened around the circumference and connected to well-grounded ⅝-inch woven copper down leads. The top 30 feet of the leads should be coated to prevent corrosion.

The height of the chimney must be limited and aircraft warning lights installed according to the requirements of the Federal Aviation Agency.

A test opening in a chimney can be costly if not included during construction. An opening for obtaining gas samples is made by inserting and firmly anchoring a standard six-inch pipe in the chimney. The pipe should extend from a few inches outside the chimney through the inner liner; a means of capping it should be available. Provision should be made for expansion of the inner lining at points where test openings are made.

Openings for test samples should be located where the gas flows in a smooth stream, usually between six diameters above the inlet and eight or nine diameters below the top. Two openings on the same horizontal plane 90 degrees apart are usually sufficient.

Openings for obtaining temperature readings can be made from two-inch pipe projecting through the liner and extending at least two inches outside. They should be located near the ladder at 10-foot intervals for the entire height of the chimney. They too should be capped when not in use.

Many chimneys have a large pocket below the inlet for collecting fly ash, but unless the ash is removed almost continuously, a pocket is not recommended. A clean-out door or other opening at the bottom of the chimney is essential for maintenance work, inspections, and cleaning.

An encaged safety ladder of noncorrosive metal anchored on the outside should extend the full height of the chimney and also connect to at least one catwalk encircling the chimney. Ladders and catwalks facilitate taking gas samples, servicing lights and lightning rods, and inspection and maintenance of the chimney. Inside ladders corrode quickly and are not safe.

A cap is an important accessory because it prevents a great deal of deterioration in the chimney from moisture, especially in high-temperature chimneys. The caps are made of cast iron or special heat-resistant, noncorroding alloys.

RESIDUE HANDLING

From 5 to 25 per cent of refuse by weight, depending on type, that is charged into an incinerator remains as residue after completion of the combustion process. This residue is a mixture of unburned refuse, ashes, tin cans, and other noncombustibles. It must be removed from the furnace, either manually or mechanically, and thoroughly quenched to eliminate fire, smoke, and odors, and it must be taken to a disposal site. Some components of the residue, such as tin cans and other metals, are sometimes salvaged, either at the plant or at the disposal site.

Batch Type Collection

Batch-feed furnaces are equipped with ash hoppers underneath the grates for intermittent reception of residue, and they usually are also equipped with dumping grates for discharging the ash residue. In the interests of economy and flexibility of operation, ash hoppers should be big enough to store the residue from several hours of burning. Quenching of residue, either with water from spray nozzles beneath the grates or by dumping into a water bath, is essential to reduce fire hazards. To withstand the heat of the residue, the thermal shock resulting from the sudden chilling effect of the quenching spray, and the severe wear from the abrasive residue it is customary to line ash hoppers with a hard-burned, tough, vitrified brick. Usually each hopper is equipped with discharge gates of watertight construction. Plants in which ash hoppers are used usually have an "ash tunnel" so that trucks can be driven directly under the hoppers to receive the residue. This tunnel should be paved,

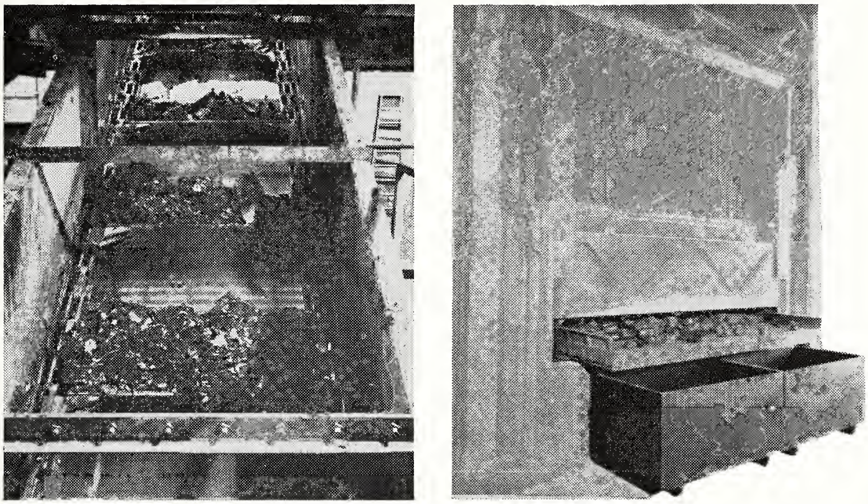


Fig. 77. Ashes can be discharged from incinerators continuously, as they are at the 73rd Street incinerator in New York where a conveyer belt is used to take the quenched ashes to a storage hopper (left). If the volume of ashes and other conditions permit, the ash may be discharged directly into portable containers (right).

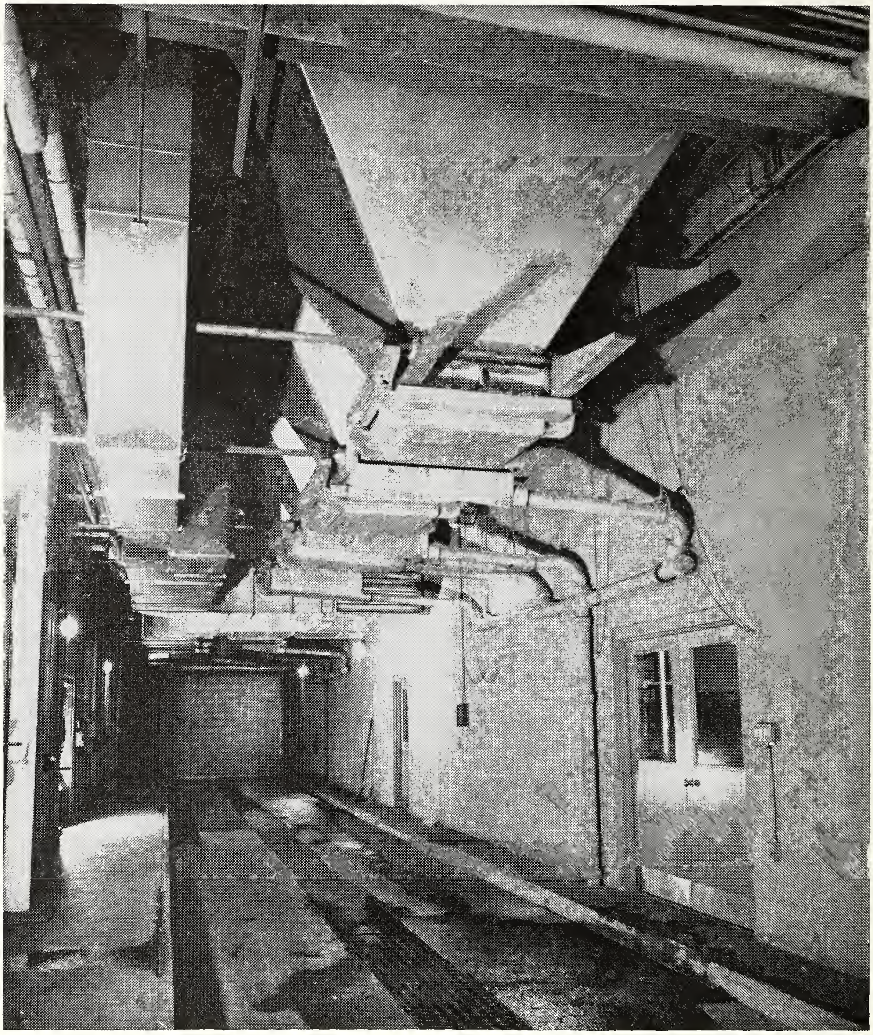


Fig. 78. Overhead discharge hoppers for quenched ashes from batch-feed incinerators, with drive-through so that ashes can be put into trucks directly from the hoppers.

well drained, and well ventilated. The cross-section area should be large enough to permit trucks and equipment to maneuver in it.

Dust and steam are rapidly removed from the ash tunnel by two methods: suction fans or blowers to utilize the exhaust as combustion air, and natural draft through direct duct connections with the annular space in high chimneys.

If final burning of refuse is allowed to take place in the ash hopper or if more residue is allowed to collect in the hopper than the spray nozzles can quench, serious damage can be done to the grates, to the grate supporting members, and to the operating mechanism.

Conveyer Type Collection

In large plants, especially those in which continuous-feed type furnaces are used, residue is discharged continuously into a water trough or tank long enough to receive the residue from all chutes (residue and siftings). An endless conveyer system drags the settled ash from the bottom of the trough up an incline to allow most of the quenching water to run off before the residue is put in trucks or containers. Noncombustible material in the residue, such as steel rods and baling wire or unburnt rags, is removed from the conveyer from time to time to prevent jamming. A rotating screening mechanism and high pressure water spray can be installed at the upper end of the conveyer system to clean and separate ashes and similar materials from tin cans if a salvage operation is desired.

Because the conveyer system is subject to a great deal of wear and requires more than occasional repairs, a stand-by conveyer should be available to assure reliable operation. The conveyer should have wearing shoes, replaceable rails and bottoms, and hard alloy steels for the chains.

Hauling

The transportation of incinerator residue in open trucks through city streets, especially for long distances, is a potential nuisance and may cause complaints. Care should be taken with quenching, draining, and cooling operations so that residue does not drip, smoulder, or give off offensive odors while it is being hauled to a disposal site. Some cities have solved this problem and reduced the cost of residue handling by using demountable, drainable, and watertight containers that can be placed beneath the ash hoppers, transported, and dumped with fork lift or hoist trucks.

For hauls of 20 miles or more it is advisable to explore the possibilities of using a truck transfer station or transportaion by rail or by large semi-trailer over-the-highway vehicles.

Architecture and Construction

The best design and construction for an incineration plant are simple, functional, economical, and attractive. Although technicalities of incineration plus the usual economies expected of a city impose restrictions, they also present a challenge to the architect to design a plant that is pleasing to the eye. Parts of the incinerator and equipment that are not usually housed within the main building—fly ash collectors, expansion chambers, fans, and storage bins, for instance—are often unsightly. However, plant design and layout can be such that the components become a part of the over-all design and do not detract from well proportioned and good looking buildings.

Since incineration is an industrial-type process, the first step in design and construction is a mechanical engineering one. Agreement must be reached on what kind and size plant is necessary and what kinds and amounts of furnaces and equipment are to be used. Architectural plans must be based on engineering layouts.

Most municipal engineering staff members do not have the specialized knowledge necessary to plan an incineration plant, so a consulting engineer is usually retained. What is expected of the consultant? First, a plant that operates well at full capacity with as little maintenance and repair as possible; second, a plant that is nuisance-free—that meets all locally imposed regulations and is acceptable as a good neighbor.

A good consulting engineer will also see to it that city officials are reasonably well informed on the design and operational problems of various types of plants and equipment so that those best suited to a city's needs can be built.

Construction involves the plant buildings, the furnaces, and other parts of the incinerator.

Plant Building

Foundations. Reliable soil samples and tests to determine bearing values are extremely important in designing and constructing a foundation. With average soil conditions, simple, reinforced concrete spread footings provide ample support for furnaces, combustion chambers, breechings, boilers, outer walls, and interior columns. If, however, the soil is relatively unstable, it may be necessary to use pilings to provide sufficient bearings, through "skin friction" or by sufficient depth to reach a firm stratum of earth or a combination of both. Frequently the site for a municipal incineration plant was formerly a dump, a marsh, or both.

The most difficult part of the foundation excavation is for the storage pit. The storage pit is nearly always built before the excavation is done for the rest of the building. The earth from the pit excavation is used to fill adjacent areas; thus the foundation adjacent to the pit can be built on firmly compacted ground. If the pit is considerably lower than the normal ground water table, the pit may have to be pumped until enough of the building above the pit has been built that hydrostatic pressure has been balanced. Filling the completed storage pit with water has also been used successfully in place of pumping. Watertight construction of the pit through the use of dense concrete, temperature reinforcement bars to prevent cracking, and water stops at all expansion and construction joints below ground water level is important. Waterproofing that part of the exterior of the storage pit that is below ground level is also recommended.

The foundations for chimneys are a special design problem and are not considered here.

Supporting Structure. Steel framing in standard shapes for beams, columns, purlins, and so on is preferred for the supporting structure of the average municipal incineration plant because it is economical. Reinforced concrete usually is not suitable because it cannot withstand the rapid temperature changes, intense heat, and vibration to which incineration plants are subjected.

Steel shapes are usually delivered with a coat of protective paint already applied. Before they are put into use they should be given a second coat of protective paint to help prevent corrosion and to cover unpainted parts such as welds and bolts. Structural members that are used in building rectangular furnaces, combustion chambers, breechings, flat arch refractory ceilings, and suspended refractory sidewalls must be protected from the heat and changes in temperature by refractory materials, fiberglass blocks, asbestos blocks, or other noncombustible materials. Temperatures vary widely in incineration plants. In northern climates the temperature of the plant near the furnaces at the end of the operating week may be as high as 130° F., while on weekends when the furnaces are not in operation the temperature may be near freezing. Provision must be made in the structure for expansion and contraction caused by these changes to prevent buckling and warping.

Structural parts that support the traveling crane, the tipping room floor, and charging gate mechanisms are subjected to live load stresses of considerable intensity and to concentrated static loads, as well as changes in temperature. They must also be able to accommodate expansion and contraction caused by incinerator operation. Furthermore, after several years of operation, crane rails become uneven and crane wheels become "egg-shaped," which may, by vibration, impose additional stress on the supporting structure.

Some special problems, such as support of the tipping floor roof with long span beams or provision of adequate rigidity against wind stresses, may require especially designed steel framing, which usually proves more satisfactory and more economical than standard steel shapes.

Interior Walls and Ceilings. Easily cleaned, impervious surfaces are important in the maintenance of the interior walls and ceilings of an incineration plant. Concrete block with an impervious surface or hollow structural tile with a salt glaze finish are economical and serviceable materials. Ceramic tile has been used with good results in many plants but it is usually too expensive for general use. It is ordinarily justified only in washrooms, showers, locker rooms, and lunchrooms.

Whatever material is used, it is important to choose colors that are both practical and pleasing to look at. Attractive appearance does much to boost employee morale.

Floors. The most economical as well as the most practical kind of floor for a municipal incineration plant is reinforced concrete or flat slab construction. In areas of the plant where the floor is exposed to a great deal of moisture and abrasion, such as the tipping floor, stoking floor, ash tunnel, and maintenance shop, it is well to consider using one of the many surface hardening and waterproofing compounds that help preserve the top layer of cement and fine aggregate.

Ventilation and Heat. The ventilation of an incineration plant is much more than a matter of opening doors and windows and allowing the air to circulate.

To safeguard the neighborhood from odors and dust, a plant should be operated with slight negative pressure in those areas where nuisances are likely to originate. It is necessary to bring air into the building, however, to prevent more negative pressure than is wanted, especially during the winter when the doors and windows are usually closed. By taking most of the combustion air through a duct at the top of the storage pit, it is possible to draw in some of the dust and odors produced by the refuse dumping and handling and to prevent them from spreading.

The ash removal floor may be a particularly steamy and dusty one. However, by taking part of the combustion air from this area or by providing an exhaust fan and duct system, dust and steam can be cut down a great deal.

Offices, lunchrooms, locker rooms, and washrooms should be ventilated independently of the rest of the building, with a slight positive pressure at all times. Plants in cold climates must be heated in some parts—offices; lunchrooms; washrooms; maintenance shop; scalerooms; charging, tipping, and stoking floors; ash handling areas. Air taken into the plant to alleviate excessive negative pressure must also be heated.

Heat may be provided by separately fired boilers or by using waste heat from the furnaces. (The sale of waste heat from incinerator furnaces is discussed in Chapter 10, Salvage and Reclamation.) If furnace heat is used, the hot exhaust gases are diverted to a low pressure boiler and from there to the chimney by means of dampering devices or induced draft fans. If waste heat from the furnaces is not used, small oil burning boilers can furnish heat for offices, lunchrooms, washrooms, and locker rooms. In cold climates the equipment can be used to provide heat on weekends when the plant is shut down. Offices and other areas away from the furnaces should be heated and air conditioned to about 70° F. and other spaces to about 55° to 60° F.

Lighting. Good lighting in an incinerator building need not be expensive if it is well planned. The most important thing is the correct amount of light for each area to promote efficiency and safety. Excellent lighting must be provided near the storage pit, moving machinery, hot surfaces, ladders, stairways, and other hazardous locations—an intensity of about 50-foot-candles is recommended.

A lighting intensity of 7- to 10-foot candles is sufficient on the tipping floor; on the charging and stoking floors an intensity of 25-foot candles should be maintained. Offices, lunchrooms, locker rooms, and washrooms require an intensity of 50- to 75-foot candles.

Local switches, rather than a few main switches that control large banks of lighting equipment, are an operating economy and cost little additional to install.

Facilities for Employees. Ample and comfortable facilities should be provided for employees. Impervious and noncorrosive materials, such as stainless steel and ceramic tile, should be used in washrooms, shower rooms, and locker rooms; sanitary facilities must be installed in compliance with local plumbing codes. The locker rooms should be big enough for two metal lockers for each employee (one for work clothes and one for street clothes) and for dressing space.

In many new plants, cooking facilities—stove, refrigerator, sink, tables, and chairs—have been provided for employees who want to prepare their own meals.

Drinking fountains, strategically located, usually pay big dividends in time saved.

A freight elevator is most advantageous in large plants with many floors.

Safety Facilities. Accepted safety practices used in industrial plants should be used in incineration plants also. Wherever possible, catwalks and stairs should be provided instead of movable ladders. Railings and toeboards around all upper level walkways and stairs also help prevent accidents, especially from falling tools. If ladders are necessary, they should be fixed and provided with hoop enclosures; they should also be long enough to extend two or three feet above the landing place in order to help prevent falls.

Safety equipment such as hip-height railings and chain and waist belt should be mandatory for employees working around charging doors in direct overhead charge type plants.

Special-purpose fire extinguishers and fire hose stations should be strategically located throughout the plant, as recommended in local fire control regulations. Fire occasionally breaks out in the storage pit and it is essential to have fire fighting equipment, including fire hose and appurtenances, to control pit fires. Carbon dioxide extinguishers have been effective in extinguishing small pit fires. Large plants may have a separate water standpipe system for such emergencies.

Some refuse causes explosions and fire, especially when batch-fed into a furnace. Naphtha and lacquer thinners in a free state or in combination with other materials, for instance, are naturally hazardous. But some substances that normally are not dangerous, such as flour and sawdust, may cause violent explosions when dropped into a blazing furnace. Moreover, sealed containers develop tremendous pressures when subjected to furnace heat and also explode.

It is recommended, therefore, to protect plant employees and equipment, that such materials be rejected for incineration but if they are not all employees exposed to such dangers be required to use safety goggles or face safety shields.

Exterior Walls and Windows. Face brick has been preferred for the exteriors of incineration plants for many years. It is usually a veneer backed up with hollow structural tile. Concrete block and stone veneer are also used. Trim is usually of cut stone or precast concrete.

If an incineration plant is to be built in an industrial area, economies are possible if an industrial-type material, such as transite or sheet aluminum, is used. Before final selection of the exterior material is made, however, it is essential that the limitations of inexpensive materials be understood.

The important thing about the outside of the building is that it be easy to clean and impervious to water, dust, and gases if it is to be satisfactorily maintained.

An important factor in the appearance of an incineration plant is the windows. Although adequate ventilation can be supplied by air conditioning, for psychological reasons it is well to have windows that open, especially if the plant is in a part of the city where escaping odors do not cause a serious problem.

Glass block gives a plant a modern, dressed-up appearance and the light that filters through it is soft and pleasing. It also is durable, easily installed, and not expensive.

In the operations parts of the plant, projecting industrial type steel or aluminum sash are suitable; double hung or casement type windows are often preferred for offices, lunchrooms, locker rooms, and washrooms.

Noncorrodible screens should be provided for all ventilating sash, and window shades or venetian blinds are recommended where protection against sun glare is important.

Roof. The roof of the building is usually made up of precast slabs of lightweight concrete or other fire-resistant material, a three-ply hot asphalt mopped roofing application, and a layer of fine gravel.

Landscaping. Every municipal incineration plant, no matter how large or small, should be pleasingly landscaped. Shrubs and grass, relatively inexpensive to plant and maintain, pay big dividends in public relations in the neighborhood and in the entire city. The layout of the walks and driveways is important. Permanent materials, such as concrete, are recommended for lasting appearance and ease of maintenance.

Large plants may require professionals to plan the landscaping and an experienced gardener to maintain the grounds, depending on location of the plant and the size of the grounds.

Furnace Construction

Walls. For many years solid gravity type walls were almost always used for furnaces and chambers because labor and material costs were low for this type of wall. However, incinerators are much larger today, which makes high walls necessary and construction and maintenance of gravity type walls too costly.

Hung type walls were first tried about 1924. Essentially they consist of a series of low walls, one above another, completely supported on steel or cast iron shelves or hangers supported by steel columns. Each section or "wall" is independent.

The construction principle is entirely different from those used for gravity type walls. Heavy structural steel columns, spaced 3 to 5 feet apart, are framed on the outside of the chamber. A framework of horizontal and vertical heat resistant castings is securely fastened to these columns to support and retain the refractory. A shelf on the horizontal bar supports the entire weight of each wall section. Refractory brick and tile are designed with interlocking treads on the sides and slots

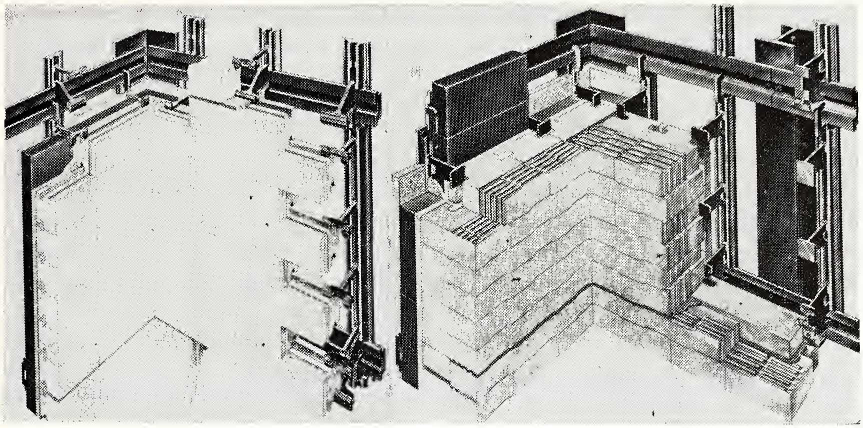


Fig. 79. Sectionally supported hung walls are usually used in modern incinerator refractory construction. They may be insulated or air-cooled. The wall shown left is for use in ignition and combustion zones of the incinerator; the one at the right is for use in zones in which temperatures are lower, such as the flues.

or offsets at the back. The first row of tile is set on the shelf and the tiles are held to the framework by castings engaging the back slots. The second row rests on the first and the tiles are held by the interlocking treads. At intervals, as a section is being built, a row of tiles is attached to the framework by castings or fingers engaging the back slots. All tiles are dipped in a thin mixture of fire clay and water to fill irregularities before setting in place.

The height of the section depends on the weight supported; it can vary from 12 to 48 inches. There is a small gap between the top of one section and the bottom of the next to provide for vertical expansion. This opening is packed with a soft asbestos cement.

Details of wall construction vary with location of the wall in the incinerator and therefore the service required of it. In the most troublesome area—just above the grates—the wall may be up to 24 inches thick (7-inch silicon carbide brick, 2-inch air space, 4½-inch firebrick, 4½-inch insulating brick, 2-inch insulation, 4-inch ceramic glazed face tile). The combustion chamber walls and hung arches require only a 9-inch firebrick wall, a large air space, and an insulating casing of facia (aluminum plate faced with bonded insulating material or a ceramic glazed tile). The subsidence chambers and flue linings, which are subject to much lower temperatures, need to be built only of 4½-inch brick with a 2½-inch insulating block or castable on the outside.

Suspended type walls can be justified for present day incinerators on the bases of longer life and lower repair costs alone. There are other advantages, however. Since the tiles are dipped only in a fire clay mixture, they do not adhere to each other and so can expand or contract in all three dimensions relatively free from interference. Since the vertical sections are low, the amount of expansion upward is small and amply provided for by expansion joints. Nor is the refractory subject to the expansion problems of a solid brick wall. Expansion cracks are not likely to develop and tiles are held in plumb. Spalling usually occurs only in limited areas of a refractory wall, and since a suspended wall consists of sections, it is possible to remove and replace a section or even a part of a section without disturbing other sections. A solid brick wall cannot be repaired or rebuilt in part; the whole wall must be rebuilt.

The original cost of a suspended wall may be less than that for the gravity wall because the thickness of the suspended wall is determined by the refractory and insulating needs and not by stability, as it is with a gravity wall. For example, the wall of a flue 12 to 15 feet high requires a 13½-inch refractory plus insulation and steel for a gravity wall, but only a 4½-inch refractory plus insulation and steel for a suspended wall.

Plastic refractories can also be used in suspended walls. Sectional supports and tiebacks to the steel framework are used with them.

In most large incinerators it is necessary to protect the refractory lining from external damage. This is done by an outer brick wall, a ceramic tile facia, or removable metal plates fastened to the buckstays.

Floors. The floors of the furnace, combustion chamber, subsidence chamber, breechings, and chimneys, when built of firebrick, are usually made up of three parts. A layer of hollow structural tile is laid on the concrete floor or footing in such a manner that air can circulate through the tiles and cool the floor and insulate the supporting structure. The tiles are covered with a layer of insulating brick over which the firebrick is placed. Silicon carbide brick is preferred in fly ash settlement chambers in which a wet floor system is used. If circumstances warrant, the tile layer may be omitted. Also, the firebrick floors may be laid without mortar if there is no risk that the open joints will fill with fine ash, causing the floor to "creep" and eventually fail.

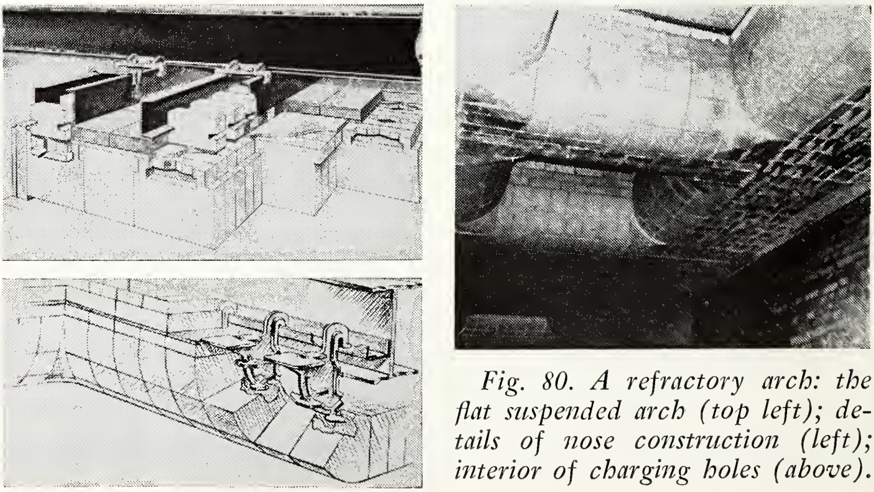


Fig. 80. A refractory arch: the flat suspended arch (top left); details of nose construction (left); interior of charging holes (above).

Arches. Every chamber and flue ceiling must be lined with refractory materials. The lining of the ceiling, known as the arch, can be of the sprung type or the suspended type.

The sprung arch is supported by abutments at the sides or ends only. It is used for short spans in which the weight at the ends of the span are not excessive. It is also used over openings for doors and observation ports. Before 1913, all arches were of the sprung type, and they required expert craftsmen to build them. There are serious disadvantages to them: unreliability, repair difficulties, and span limitations.

Suspended arches, introduced in 1913, are now used in construction of all large incinerators because of their many advantages. They are similar in principle to suspended walls in that a steel framework is supported by columns and the refractory is hung on anchors attached to the framework. The top of the refractory is usually covered with insulation to reduce the heat loss and air infiltration. The thickness and quality of the refractory are determined by service needs, not by stability needs, as they are with sprung arches. Suspended arches are cheaper for the long spans, provide better for expansion, require less skill to build, usually last longer, allow for more flexibility in the design of the furnace, and are much easier and cheaper to repair.

Operation and Maintenance

Operation

Incineration can be efficient. Refuse can be reduced to a minimum through a combination of high burning temperatures, semi-automatic temperature and air controls, controlled feeding, and mechanical stoking. Production of residue acceptable as fill material without cover is primarily a matter of correct burning temperatures and time and adequate agitation of the refuse while it is burning. A well operated incinerator produces residues that vary from 5 per cent by weight of refuse relatively free of noncombustibles to 25 per cent by weight of mixed refuse; and from 3 per cent to 15 per cent by volume. The amount of unburned organic matter in a good residue varies from 2 per cent to 7 per cent by weight.

High-temperature combustion effectively destroys odors and reduces noxious gases to tolerable traces. Particulate matter can be trapped so that the amount that escapes through the stack is within limits set in air pollution control ordinances. The noise from a fully enclosed incineration plant is not loud enough to be objectionable in most neighborhoods.

Maintenance and Repairs

The modern incineration plant is dirty, dusty, odor producing, and requires more than normal routine care to even approach a power plant in spit-and-polish appearance and trouble-free operation.

An annual budget for maintenance and repairs approximating 5 per cent of the total capital costs of the plant usually is adequate, particularly if the plant is well designed and constructed; if it was properly tested, adjusted, and broken in; and if it is always kept in good condition. Maintenance and repairs can be expected to cost between 10 per cent and 15 per cent of the total cost of operation, depending on the size and type of plant. Approximately half the cost will be for labor and the other half for materials.

Routine maintenance is preventive. Weekly inspections, cleaning and greasing, removal of clinkers and slag, minor repairs to easily accessible parts of the plant and machinery, and less frequent inspections and repairs to hard-to-get-at parts of the plant will help prevent major damage and emergencies.

In addition to routine maintenance and repairs, major repairs are needed occasionally; reconstruction and modernization of furnaces, cranes, and other parts of the plant are needed less frequently; and a complete overhaul and modernization of the plant is necessary perhaps every 25 years or so.

For routine maintenance and repairs it is necessary to stock firebrick and insulating brick, refractories, parts and links for grates and chains, and other parts of the plant components and equipment that break or wear out frequently. If extra pieces of equipment, such as cranes, are kept on hand, efficient and complete repairs can be made to parts that break without having to shut down the plant.

Even an average size incineration plant should have a machine shop, an electrical shop, and a welding shop for repairs and maintenance work.

The most important factor in good maintenance of an incineration plant is well trained, conscientious employees. If the plant is to operate efficiently, they must take personal responsibility for tending the plant and equipment and for reporting defective parts and faulty mechanical operations. Such employees will concern themselves not only with replacing worn out or defective parts, but will also try to analyze the reasons why equipment wears out or breaks and suggest improvements in operation and maintenance.

Air Pollution Control

Since the municipal government is usually responsible for the enforcement of local air pollution control ordinances, it is important that municipally operated facilities be examples of compliance. Indeed, considerable attention has been focused on air pollutants discharged by central incinerators.

Local Ordinances

Many cities have air pollution control ordinances. Almost all include provisions for the control of smoke, odors, and fly ash; a few also include provisions for control of gaseous discharges.

Local air pollution control ordinance provisions cannot be standardized because local conditions differ. Nevertheless, most ordinances are based on uniform recommendations for combustion of fuels.

The heterogeneous character of refuse, its low unit weight, its changing combustibility, and the amount of cool air needed in an incineration plant make it difficult to set uniform standards for excess air and temperatures.

The situation is further complicated by the fact that even if an incineration plant does, during a test period, meet the standards set by law, the results are for that test period only. It is necessary, therefore, that emission tests cover a wide range of operating conditions to insure, as far as possible, that a plant operates satisfactorily under all conditions. The lack of a simple, reliable method of measuring particulate discharge from municipal incineration plants is a handicap.

Smoke

Smoke of the visible black type is only occasionally a serious problem with central incinerators. Most cities use the Ringelmann Chart for Grading Density of Smoke (described in the United States Bureau of Mines Informational Circular 6888) as the standard for determining visual smoke emissions.

To use the chart, the color and density of smoke emitted from a chimney are compared with black cross-hatched lines of various widths on the Ringelmann Chart and the emission is given a number accordingly. If the number is greater than that permitted by local ordinance, the incinerator is in violation of the law. The chart has been reproduced in a number of handy devices such as the one shown in Figure 81.

While most cities use the Ringelmann Chart as the basis of ordinance standards, it is not a universally adopted measuring technique. And in most cities no limits have been set in the ordinance as to how long smoke

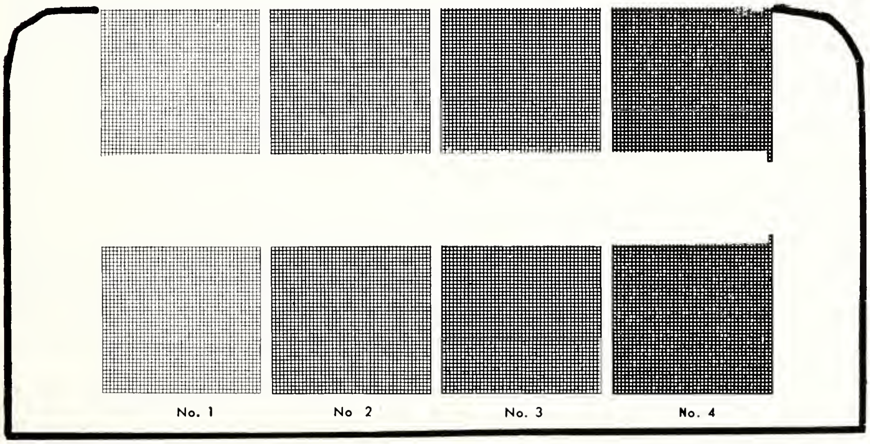


Fig. 81. Smoke emitted from a stack is compared with this chart to determine if it is light enough to meet standards. The Power's Microringelmann Chart above, a direct facsimile reduction of the standard Ringelmann Chart, is reproduced by permission of McGraw-Hill Publishing Company.

of a certain color and density can be emitted, although the trend is toward more such provisions.

The most serious effort to standardize time limits on visual black smoke emission was made by the American Society of Mechanical Engineers in a 1949 information bulletin, "Example Sections for a Smoke Regulation Ordinance," drawn up by the Model Smoke Law Committee of the Fuels Division of the society.

The society's recommendation on smoke emission reads:

> No person shall cause, suffer or allow to be emitted into the open air from any fuel-burning equipment, internal combustion engine, premises or open fire, smoke the shade or appearance of which is equal to or darker than No. 2 of the Ringelmann Chart excepting:
>
> A. Smoke the shade or appearance of which is equal to but not darker than No. 2 of the Ringelmann Chart for a period or periods aggregating 4 minutes in any 30 minutes;
>
> B. Smoke the shade or appearance of which is equal to but not darker than No. 3 of the Ringelmann Chart for a period or periods aggregating 3 minutes in any 15 minutes, when building a new fire or when breakdown of equipment occurs such as to make it evident that the emission was not reasonably preventable.

Fly Ash

Limited data have been published on the amount of fly ash emitted from industrial and municipal incineration plants. However, design factors, as well as operating conditions, have a marked effect on fly ash emission. For example, the greater the burning rate per square foot of grate surface, the greater the amount of fly ash emitted. Data also show that when other factors are constant in an incinerator, fly ash emissions can be expected to increase if a forced draft system is used instead of a natural draft system.

TABLE 22

PARTICLE SIZE OF FLY ASH EMITTED FROM GANSEVOORT INCINERATOR, NEW YORK CITY

Size	*Per Cent by Weight*
Plus 120 microns	5.8
Plus 90 microns minus 120 microns	6.5
Plus 60 microns minus 90 microns	17.7
Plus 40 microns minus 60 microns	13.2
Plus 30 microns minus 40 microns	12.5
Plus 20 microns minus 30 microns	1.9
Plus 15 microns minus 20 microns	3.4
Plus 10 microns minus 15 microns	21.2
Plus 5 microns minus 10 microns	5.8
Minus 5 microns	12.0

TABLE 23

CHEMICAL ANALYSIS OF FLY ASH EMITTED FROM GANSEVOORT INCINERATOR, NEW YORK CITY

Component	*Per Cent by Weight*
Organic	14.5
Inorganic	85.5
Silica as SiO_2	36.0
Iron as Fe_2O_3	10.0
Alumina as Al_2O_3	27.7
Calcium as CaO	8.5
Magnesia as MgO	3.4
Sulfur as SO_3	9.7
Sodium and potassium oxides	4.7
Apparent specific gravity	2.58

Burning temperatures and the corrosive nature of incinerator gases limit the types of fly ash control systems that can be used.

Tables 22 and 23 give particle size and chemical analysis, respectively, of fly ash emitted from the Gansevoort Incinerator, New York City; and Tables 24 and 25 give the same information for the South Shore Incinerator in New York but it is also given by source.

Dry Collection. Most municipal incineration plants cannot meet the ASME-recommended fly ash limitations by using dry fly ash collection systems alone, and, therefore, require special fly ash removal equipment. However, some incinerator fly ash has been controlled by the use of refractory baffles, which settle fly ash in large, low-velocity subsidence chambers, and by mechanized collecting systems, such as multicone centrifugal separators, which have been operated successfully in a number of large plants. Gravity settling of fly ash by low velocity sedimentation methods—with or without baffles, checkerwalls, and the like—requires unusually large chambers and a large plant site, which for some cities are impractical and costly.

Wet Collection. Water spray systems have been used in incinerator breechings to control fly ash but they are relatively inefficient. The probability of a dust or fly ash particle colliding with a water droplet is remote. Furthermore, the high gas temperatures in the breechings (900° to 1,500° F.) may vaporize the water containing dust particles and the particulate matter may be re-entrained in the gas stream. In addition, the velocity of the gas prevents the water from falling uniformly so that some parts of the gas stream are not subjected to any wetting at all.

Wet impact collection devices have been used effectively for fly ash control in municipal and industrial incinerators. This method is more effective than water sprays because the gas stream is brought into close contact with water film that eliminates the possibility of re-entrainment of the fly ash. There are a number of types of wet collection systems in use. Among them are wetted metal or refractory impact baffles and

TABLE 24

PARTICLE SIZE OF FLY ASH SAMPLES FROM SOUTH SHORE INCINERATOR, NEW YORK CITY, BY SOURCE

(Per cent by weight)

	Source of Sample			
Sieve Size[1]	*Upper Flue*	*Expansion Chamber*	*Base of Stack*	*Emitted*
Plus No. 20	1.4	1.0	0.9	0.4
Plus No. 60 Minus No. 20	31.5	34.5	31.8	4.1
Plus No. 100 Minus No. 60	24.8	31.4	32.6	8.8
Plus No. 200 Minus No. 100	25.4	22.9	25.1	20.2
Plus No. 325 Minus No. 200	8.5	5.6	5.6	38.4
Minus No. 325	8.4	4.6	4.0	28.1

[1] Numbers refer to United States standard sieve; the higher the numbers the smaller the openings.

TABLE 25

CHEMICAL ANALYSIS OF FLY ASH SAMPLES FROM SOUTH SHORE INCINERATOR, NEW YORK CITY, BY SOURCE

(Per cent by weight)

	Source of Sample		
Component	*Upper Flue*	*Expansion Chamber*	*Emitted*
Organic	0.5	0.6	10.4
Inorganic	99.5	99.4	89.6
Silica as SiO_2	50.1	54.6	36.1
Iron as Fe_2O_3	5.3	6.0	4.2
Alumina as Al_2O_3	22.5	20.4	22.4
Calcium as CaO	7.9	7.8	8.6
Magnesium as MgO	1.8	1.9	2.1
Sulfur as SO_3	4.3	2.3	7.6
Sodium and potassium oxides	8.1	7.0	19.0

enclosed tank type scrubbers. Such devices operate under a medium draft loss and produce satisfactory fly ash dust loadings.

With any wet collector system, the problem of separation of the collected solids from the water slurry is important in preventing a sewage disposal problem and preventing recirculation or reuse of the water.

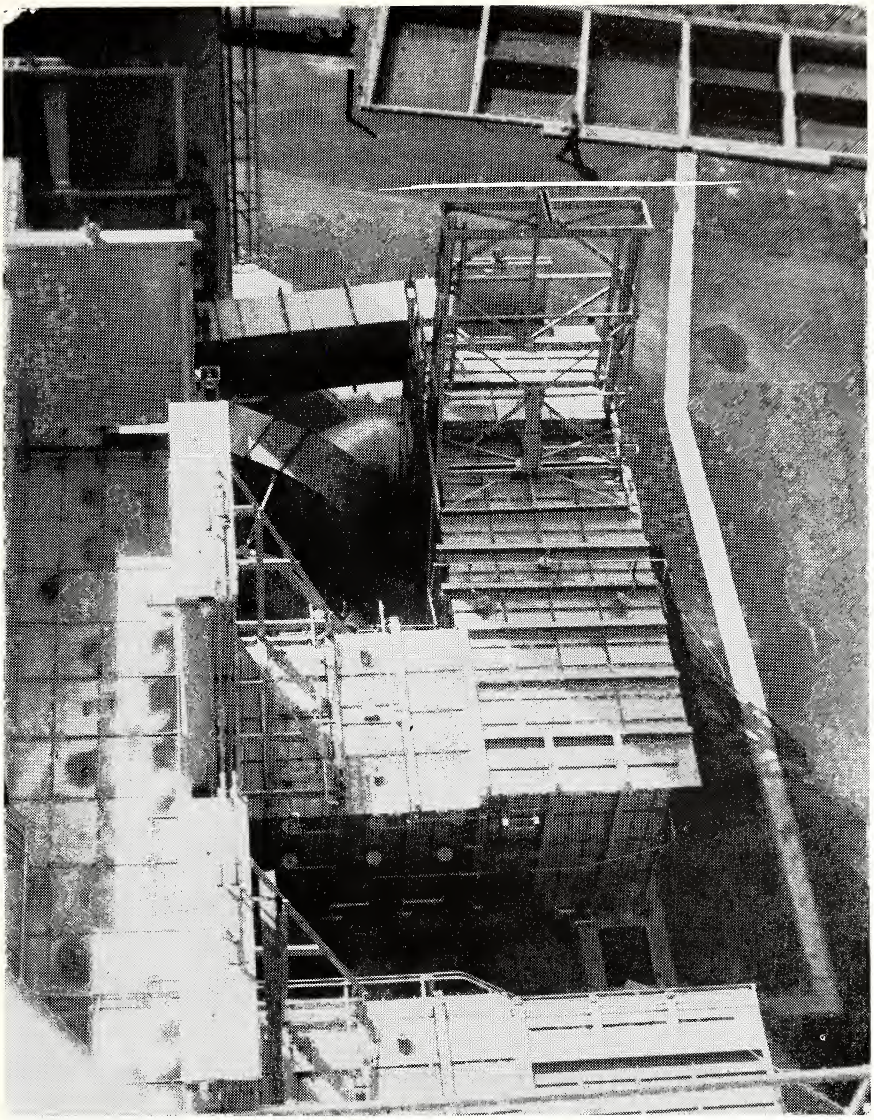


Fig. 82. A wet type fly ash collection system. The fly ash gravity settling tanks are upper right.

Figure 82 shows gravity settling tanks used in a municipal incineration plant to settle fly ash from the slurry of an efficient wet impingment collection system. The water can be reused or wasted, depending on the local water supply and costs.

The main disadvantages of wet collectors are that they use a lot of water and create corrosion and maintenance problems.

Induced Draft Fans. Some types of fly ash removal equipment cause such a high draft loss that the draft at the furnace is not sufficient to properly operate it. If such is the case, it is necessary to install induced draft fans to boost the chimney drafts.

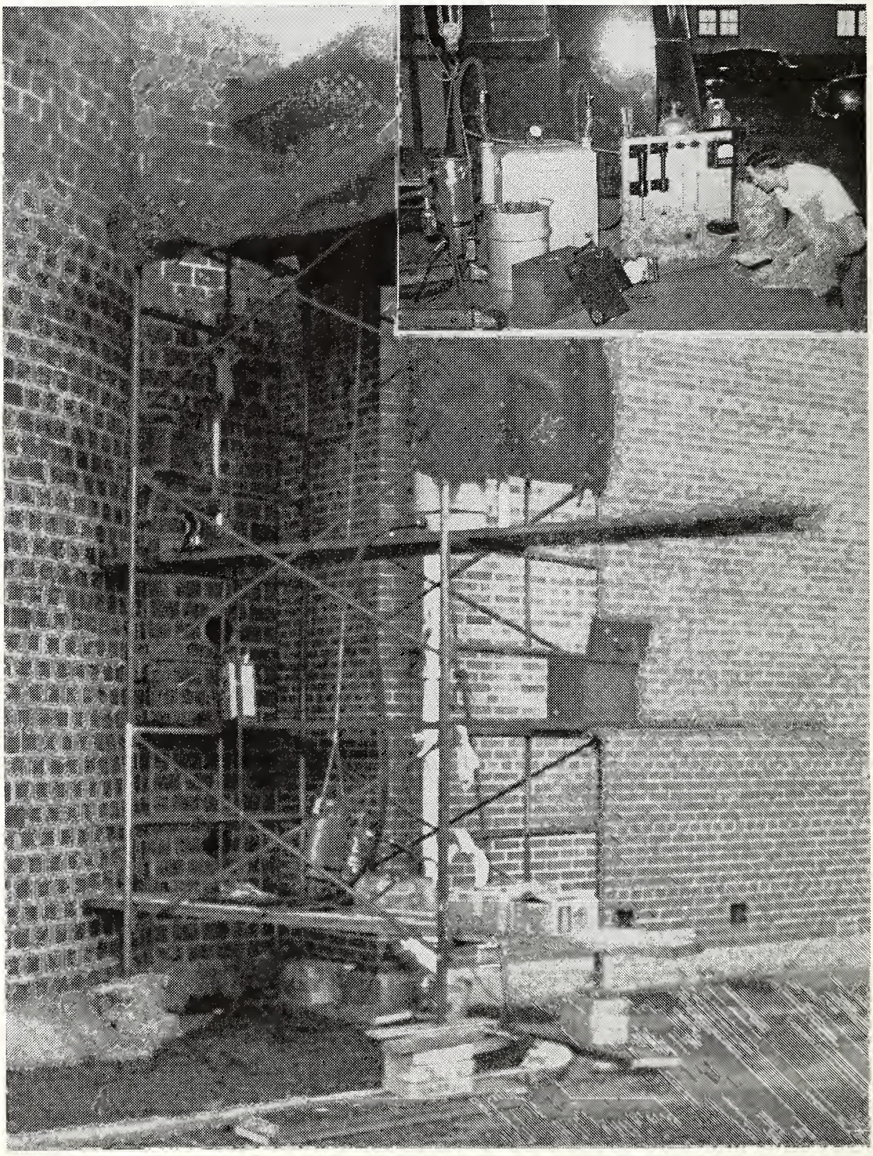


Fig. 83. Tests for particulate matter discharge at the municipal incinerator in Rochester, New York, require that scaffolding be put up. Gas flow measurement instruments are read during an air pollution test at an incinerator (inset).

Testing Procedures. The ASME Test Code for Dust-Separating Apparatus and a Western Precipitation Corporation bulletin on gas and dust measurement are the two standard documents on test procedures and techniques.

The ASME code has been described as the best set of standards adaptable to industrial and municipal incinerators. It describes procedures, techniques, and equipment to meet four basic testing requirements:

1. Securing a truly representative sample of the effluent gases and particulates. This is done by "isokinetic" sampling equipment and techniques. This is best done by using the static balanced tube sampling techniques.
2. Accurately filtering and weighing the samples of particulates.
3. Accurately measuring the samples of gas volume.
4. Devising methods, equipment, and techniques to measure continuously temperatures, pressures, gas composition, velocity, and gas density of the samples of gases and of the main effluent gas stream.

Figure 83 shows part of the instruments needed to perform a field stack test in conformance with the ASME test code.

As part of the performance tests for a new incineration plant and to demonstrate compliance with local air pollution control ordinances, it may be necessary to require air pollution dust-loading emission tests.

Recognizing that standards for permeable stack emissions and the methods and instruments for measuring emissions were developed primarily for homogeneous fuels, the APWA has initiated a research project aimed at correcting these deficiencies, particularly for municipal incineration plants. The project calls for development of accurate instruments, valid means of measuring emissions, and the use of a standard code. In drawing up the code, seasonal atmospheric variations, geographic location, the densities of other air pollutants, and local air pollution control requirements are being considered.

6 ON-SITE INCINERATION

On-site incineration is a widely used method of disposal for combustible refuse for two principal reasons: (1) it is often desirable to dispose of refuse as soon as possible after it is produced to eliminate the need for storage facilities; (2) it does not require collection services. As discussed in this chapter, on-site incineration applies to houses, apartments, stores, industries, hospitals, and other institutions.

Pros and Cons

The storage of refuse often causes nuisances, particularly odors. Covered containers and wrapped garbage minimize some odors but under some conditions all odors cannot be reduced sufficiently. Usually there are not unpleasant odors when wastes are first put into refuse containers but they develop from bacterial action during storage. Facilities in which food wastes are improperly stored also attract rodents and offer breeding places for flies and other insects.

If, however, instead of putting refuse into a storage container and having it collected, it is put into an incinerator and burned, it can be destroyed before nuisances ar hazards are created.

If it were possible to have efficient, nuisance free incinerators for an entire city that would burn rubbish, leaves, grass clippings, and yard trimmings, as well as food wastes, collection of combustible refuse could be eliminated. The ash residue is so small that only infrequent collections of it would be necessary. Much of the noncombustible refuse could be salvaged as metal and the rest could be disposed of in sanitary landfills.

A study made in New York City indicates how much municipal refuse collection and disposal could be reduced if on-site incinerators were used citywide. (A New York ordinance requires that incinerators of approved design be installed in all new multi-family buildings.) Data were collected from three large apartment house developments with tenants of three different economic levels and extrapolated for the entire city for 1970, with these conclusions: (1) there would be 13,000 domestic incinerators that would (2) serve 1,935,000 people; (3) the incinerators would burn 2,250 tons of mixed refuse a day, (4) of which 550 tons would be residue, (5) requiring that the city collect 1,700 tons less refuse a day than it did in 1960. In other words, the amount of refuse collected would be reduced each year by about 620,000 tons at an approximate annual savings of $1 million.

Unfortunately, on-site incinerators do not always dispose of refuse without trouble. Many incinerators operate at temperatures too low to destroy odors. Odors consist primarily of oily vapors that burn completely only if combustion temperatures reach 1,200° F. or higher. To insure complete odor elimination, incinerator temperatures should be above 1,300° F.

It is possible to maintain temperatures above 1,300° F. even in a single-chamber incinerator by providing adequate air and combustion volumes and by using sufficient auxiliary fuel. The incinerator must be built to safely withstand high temperatures, however, and the auxiliary fuel burners must be located so that they can produce the required results. In any case, the use of after-burners and of adequate size subsidence chambers assures that smoke, odors, and fly ash emissions are cut down. These facilities increase installation and operating costs, however; the extent of their use must be tailored to local conditions.

The method by which refuse is put into the incinerator often has considerable effect on whether nuisances are created during burning. If any refuse is stored in the incinerator, as in a flue-fed incinerator, and later the refuse is ignited, it is extremely difficult to get efficient, nuisance-free combustion. If, however, refuse is collected in cans and brought to the incinerator for controlled charging, it is possible for the operator to burn lightweight materials first to raise furnace temperatures and to put in garbage and other odor producing refuse after the temperature is high enough. Unfortunately, not all operators know of this process of charging and some who do are too indifferent to follow it.

Refuse incineration requires supervision during the entire burning process if there are to be no nuisances. Often an on-site incinerator operator starts the incinerator and then leaves it. He may come back once or twice during the burning period, but perhaps only to shut off auxiliary burners. But other procedures and manipulations are required with modern incinerators to insure correct temperatures at all times.

Weather plays an important part in detecting odors from incinerators. Gases are discharged from chimneys, usually a considerable distance from the ground. If an incinerator is operated only when there is a wind, there is little danger of any odors being detected in the atmosphere, because the gases rise and are carried away. On the other hand, if refuse is burned on a humid day when smoke settles to the ground, odors can easily be detected in the air. Odors can be reduced by confining burning to days when weather conditions are favorable, but this is seldom expedient.

Domestic Incinerators

Domestic incinerators are used for the bulk of on-site incineration—on the basis of the total number of incinerators, on the number of tons of refuse burned, and on number of hours operated. There are two broad classes of domestic incinerators: outdoor and indoor.

Outdoor Types

The outdoor, or back yard, type is by far the most common. The simplest ones consist of a metal drum with air holes punched into the sides near the bottom. Incinerators that have a wire burning basket are probably the next most common type. Back yard burners can be quite elaborate, varying from simple concrete boxes to refractory-lined units with substantial cast iron grates and a short chimney.

Regardless of type, outdoor incinerators are not suitable for present-day living in urban areas. Combustion temperatures and the amount of air

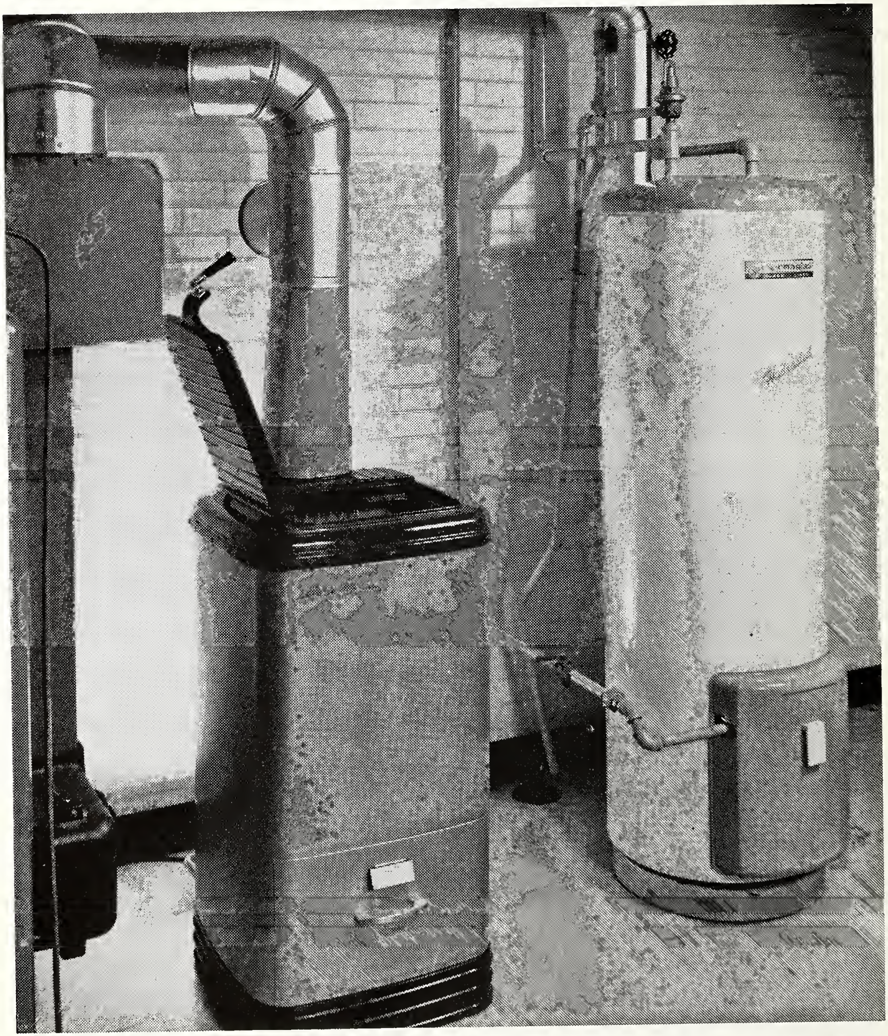


Fig. 84. Domestic incinerators are widely used where there is inadequate or infrequent collection of combustible refuse. The appearance of them is comparable to other household appliances.

needed for combustion cannot be regulated effectively or economically. The burners produce smoke, odors, and fly ash and are fire hazards to nearby buildings. This was dramatically demonstrated in the Los Angeles area in 1957 when back yard burning was limited to the hours of 4 P.M. to 7 P.M. Pictures taken just before 4 o'clock showed the area to be relatively free of smoke and haze. But pictures taken at one-minute intervals after the burning was started showed the area gradually blanketed with smoke; visibility was reduced from several miles to only a few hundred yards. Back yard incinerators have since been banned in the Los Angeles area.

In fact, the practice of burning refuse outdoors is gradually being prohibited in most large cities. Outdoor incinerators cannot be manufactured nuisance-free at a price that interests householders and justifies discontinuance of refuse collection and disposal systems.

Back yard burning may be justified in sparsely settled areas where smoke and odors are quickly diluted and it is unlikely that the burners will cause any significant air pollution problems.

Indoor Types

Indoor domestic incinerators, usually called home incinerators, are of many types, but they can be classified broadly as those that burn refuse without the use of auxiliary fuel and those that use auxiliary fuel.

Burners Without Auxiliary Fuel. Home incinerators operated without auxiliary fuel work much like outdoor incinerators. The simplest and cheapest type consists of an iron grate built into the base of a chimney. A charging door is built into the chimney above the grate and an ash pit door below. Often a complete unit is bricked into the base of the chimney. The actual burning takes place in the chimney, where there is little chance to regulate the draft. Other types are burners connected to the house chimney by a length of vent pipe. They may be simple sheet metal units or elaborate refractory-lined ones.

The advantages of this type of home incinerator are that smoke and odors are discharged from the top of the house chimney and fire and odor hazards are substantially reduced. The refuse mixture burned in them is usually a better fuel than that in outdoor burners, because leaves, grass clippings, brush, and other garden trimmings are not ordinarily carried into the house for disposal. If the burning is restricted to papers and cardboard, smoke and fly ash are the only probable nuisances. If garbage, rags, wool, rubber, plastics, and similar materials are put in with paper and cardboard, disagreeable odors result because the papers burn up quickly and high enough combustion temperatures are not maintained to burn the other refuse satisfactorily. The possibility of odor nuisance is then entirely dependent upon atmospheric conditions, which determine whether odorous gases from the chimney are blown away and dissipated or descend to the ground.

This type of home incinerator is rapidly losing its appeal to the householder. It cannot burn large quantities of garbage under normal circumstances without causing odors. The increased use of home garbage grinders has greatly reduced the refuse problem in many homes, however.

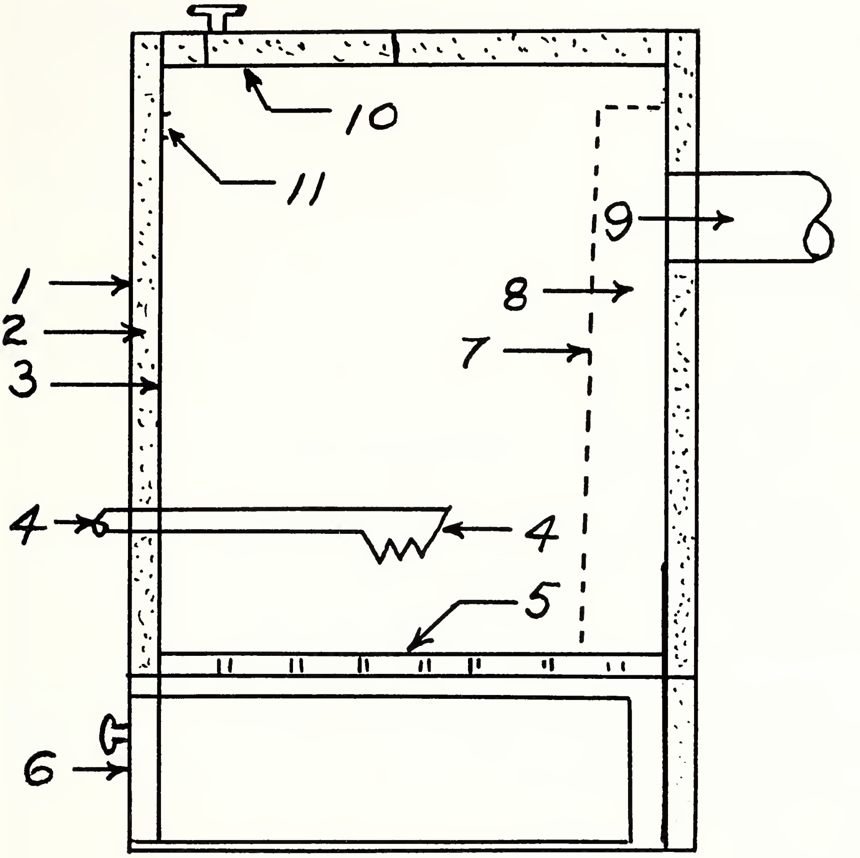
Burners With Auxiliary Fuel. The most widely used home incinerators are those that use gas as an auxiliary fuel. Many models were marketed during the 1950's. All can be classified in three general types: (1) dehydrating units, (2) high B.T.U. input units, and (3) units equipped with after-burners.

1. The dehydrating type home incinerator consists of a round or rectangular combustion chamber large enough to hold one or two bushels of refuse. The charging door is usually at the top and an ash-pit door is near the bottom. A small gas burner is located near the bottom of the chamber and is protected by a tube or deflector so that the refuse cannot interfere in any way with the gas flame. Combustion gases exit from the rear at or near the top of the burner and are vented to a chimney (Figure 85).

The operating principle of these incinerators is simple. The gas flame burns continuously and is adjusted to a gas input of from 1,500 to 3,500 B.T.U. per hour, depending upon the manufacturer's recommendation. The burner and shield heat up the air in the combustion chamber. When refuse is placed in the unit, the warmed air circulates through the material and picks up moisture before passing to the chimney. The refuse is thus dehydrated. As it dries, the temperature of it rises until it ignites. With combustion started, the refuse burns to ashes.

In practice there have been a number of difficulties with this type of incinerator. Food wastes dehydrate slowly at temperatures below 200° F. and at temperatures below 150° F. the process requires days. As a result, incinerators of this type cannot economically burn an appreciable quantity of wet refuse. If the refuse consists primarily of combustibles such as papers and cardboard, the paper next to the burner reaches ignition temperature in from two to eight hours. The flames ignite all of the papers and similar materials in the combustion chamber and the temperature within the unit rises rapidly to a peak within two to five minutes after ignition. Paper and similar materials burn comparatively quickly, however, so that the temperature drops as soon as they are consumed. It has been found that 10 minutes after ignition the temperature is usually below 500° F. No appreciable amount of garbage can be burned in so short a time and even little drying takes place. Only the hot ashes from the paper and the continued burning of partially dried garbage from previous charges provide dehydration for the freshly charged food wastes. The temperature of the combustion gases from a charge of mixed refuse usually falls below 200° F. in 15 minutes and gradually returns to a steady operating temperature of about 140° F. for the next two hours. This final dehydrating and burning period, extending over several hours, produces little smoke or fly ash but produces strong burning-garbage odors. A dehydrating incinerator cannot completely burn a refuse charge in one operation unless the material is practically all paper.

Home incinerators of the dehydrating type produce the most smoke

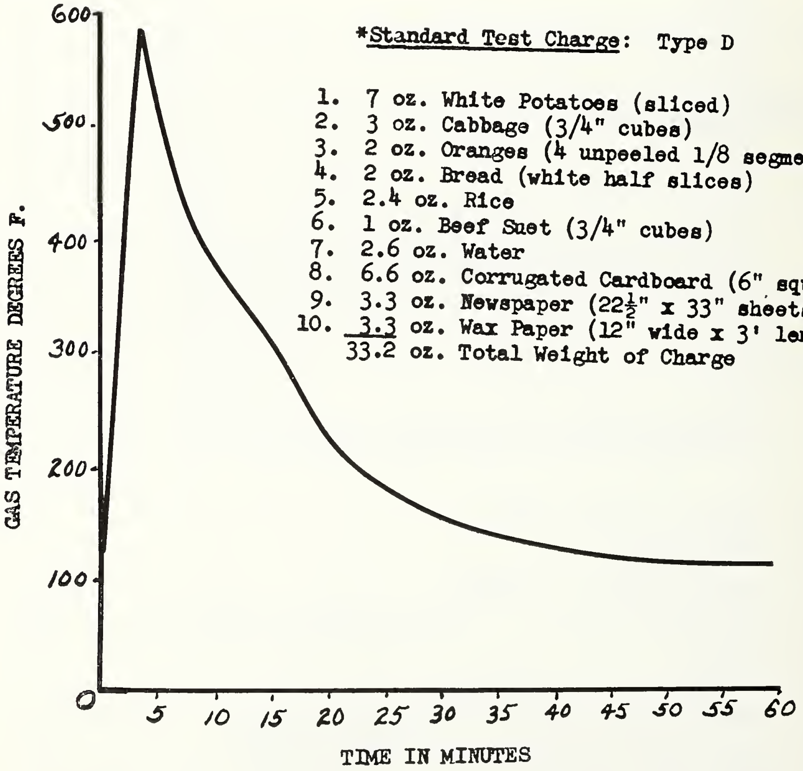


1 - Outer Metal Shell
2 - Insulation
3 - Inner Metal Lining
4 - Constant B. T. U. Gas Burner (1800 B. T. U.)
5 - Grate
6 - Ashpit Door and Pan
7 - Perforated Metal Retainer Plate
8 - Passage for Gases of Combustion
9 - Vent to Chimney
10 - Charging Door
11 - Overfire Air Ports

Fig. 85. A schematic drawing of the dehydrating type of household incinerator.

and fly ash within the first five minutes of ignition. The air supply, which is relatively constant, is regulated by the size of the air in-take holes and the chimney draft. At the start of ignition, there is usually insufficient air for complete combustion and some smoke may result. As soon as most of the paper and other high combustibles are consumed, the air supply becomes adequate for the combustion rate and the smoke practically disappears. The disappearance of the smoke makes it difficult to locate the source of odors, however. The strongest odors, as mentioned previously, usually come from burning garbage at low temperatures, which continues long after all of the paper has been destroyed.

A typical curve for an ignition cycle in this type of incinerator is shown in Figure 86. The initial and final temperatures are determined by the amount of paper and similar highly combustible materials in the refuse.



*Standard Test Charge: Type D

1. 7 oz. White Potatoes (sliced)
2. 3 oz. Cabbage (3/4" cubes)
3. 2 oz. Oranges (4 unpeeled 1/8 segments)
4. 2 oz. Bread (white half slices)
5. 2.4 oz. Rice
6. 1 oz. Beef Suet (3/4" cubes)
7. 2.6 oz. Water
8. 6.6 oz. Corrugated Cardboard (6" squares)
9. 3.3 oz. Newspaper (22½" x 33" sheets)
10. 3.3 oz. Wax Paper (12" wide x 3' lengths)

33.2 oz. Total Weight of Charge

* "Regulations for the Testing of Indoor Refuse Burning Equipment - Type D". Ordinance Number 77-F. Department of Buildings and Safety Engineering. City of Detroit, Michigan, May 3, 1956.

Fig. 86. Chart showing ignition-temperature cycle of a dehydrating household incinerator.

The dehydrating type incinerator has not yet been demonstrated to be a good general solution to home refuse disposal problems.

The electric heater home incinerator, which is in the dehydrating category, was developed for use in areas that do not have gas available for fuel, although many have also been installed in cities where there is gas. They are designed and operate on the same principle as that of the gas dehydrating type except that a hot plate is used in the electric burner.

Electricity has serious limitations as an auxiliary fuel for a home incinerator. The heater must first cook the refuse to dry out the moisture because the refuse cannot be burned until the temperature of the refuse is raised to the ignition point. If a large amount of garbage is put in the incinerator or little or no dry combustible refuse with it, it may be a long time before the garbage will be dry enough to ignite.

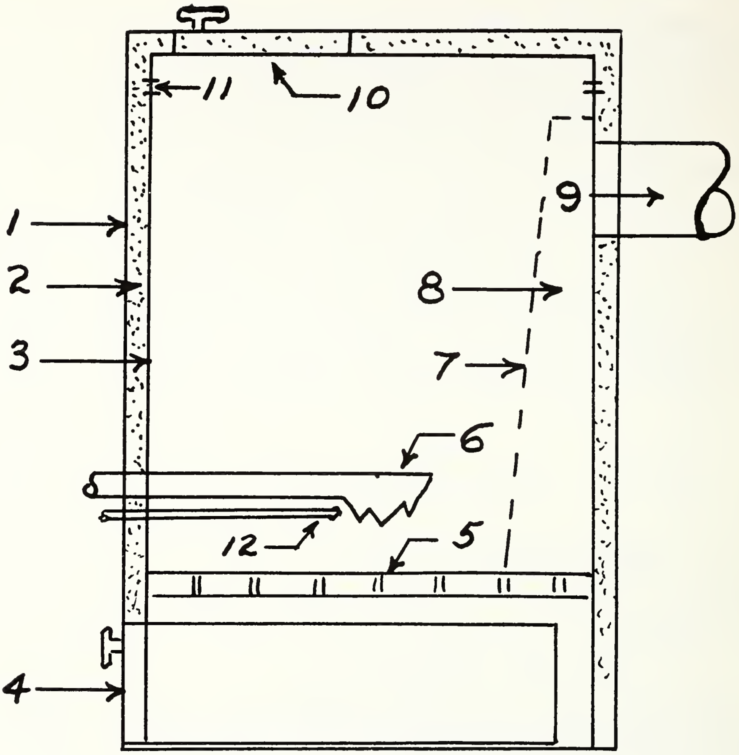
The cost of operating and maintaining electric units is usually comparable to a gas-fired unit, although it can vary with local conditions.

2. The majority of home incinerators installed in the 1950's were of the high B.T.U input type. The unit usually consists of a round or rectangular chamber that holds from one to two bushels of refuse, and is equipped with a charging door and an ash-pit door. The gases of combustion exit from the rear at or near the top. The burner is installed near the grates and is protected so that the gas flame cannot be extinguished by falling refuse (Figure 87).

An incinerator of this type also is, in practice, a storage container for combustible refuse. Refuse is put in the unit until it is full; the main gas burner is then lit, which in turn ignites the charge; the refuse is burned; and the incinerator is ready for use again as a storage container. The frequency of burning is entirely dependent upon the amount of refuse; it varies from daily operation in large families to weekly operation in small ones.

A timer is often installed on the main gas burner line so that the gas will go off automatically in the burner when the predetermined time has elapsed, eliminating the need for any further attention once the incinerator is ignited.

In practice, lighting the main gas burner ignites the dry paper in the incinerator and the temperature of the gases leaving the combustion chamber rises rapidly. At this point most of the combustion chamber air space is occupied by the refuse. The air supply is limited by the size of the air holes and therefore is insufficient during the initial combustion period for the amount of refuse. The temperature rises during this period but is below the desirable minimum of 1,300° F. The small combustion chamber volume, the limited air supply, and the low flue gas temperature make starting the period of greatest potential smoke production. As the temperature rises, gas velocities increase and the fly ash discharge increases. In about 10 minutes most of the dry paper and similar materials have burned and the flue gas temperature begins to decrease. The heat dehydrates the fresh garbage and also the garbage that remains from previous charges. Some of the garbage burns and produces odors at this



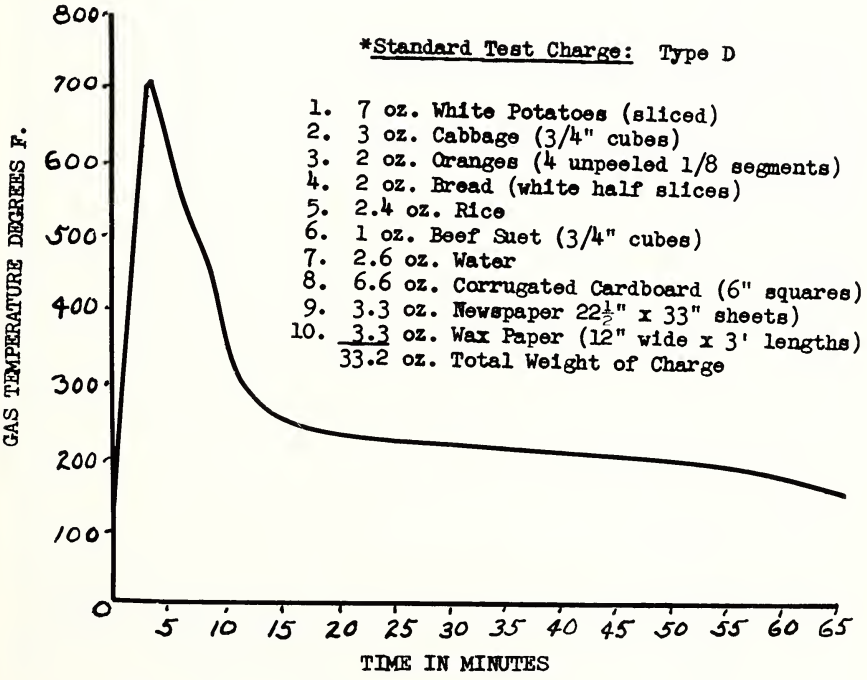
1 - Outer Metal Shell
2 - Insulation
3 - Inner Metal Lining
4 - Ashpit Door and Pan
5 - Grate
6 - High B. T. U. Input Burner (9,000 to 35,000 B. T. U.)
7 - Perforated Metal Retainer Plate
8 - Passage for Gases of Combustion
9 - Vent to Chimney
10 - Charging Door
11 - Overfire Air Ports
12 - Pilot Burner

Fig. 87. A schematic drawing of the high B.T.U. input type of household incinerator.

point because the combustion chamber temperature is considerably below that required for odor-free burning. This condition continues for a considerable time—usually for several hours and sometimes even after the main burner is shut off.

The primary purpose of the gas burner is to supply a flame of sufficient heat (from 9,000 to 35,000 B.T.U.'s per hour) to dehydrate and burn all wet refuse. Theoretically, the wet materials fall into the flames and are eventually destroyed. In practice, the paper and other combustibles burn out quickly and leave channels through the unburned refuse. The flames from the burner travel through these channels without coming in contact with the wet refuse, and at times, it has been observed, the burning of the garbage has practically stopped. If the unburned materials are agitated to break the crusted or coked surfaces and the channels are closed, the gas flames must pass through the unburned refuse and burning is speeded up considerably. It is possible to completely burn all refuse if the gas burner is operated for long enough and the unburned refuse is agitated several times. A typical curve for an ignition cycle in this type of incinerator is shown in Figure 88.

3. The performance characteristics of the dehydrating and high B.T.U. input types of home incinerators have made those incinerators unsatisfactory in cities that have and enforce effective air pollution control ordinances. This led to their prohibition in some areas and the develop-



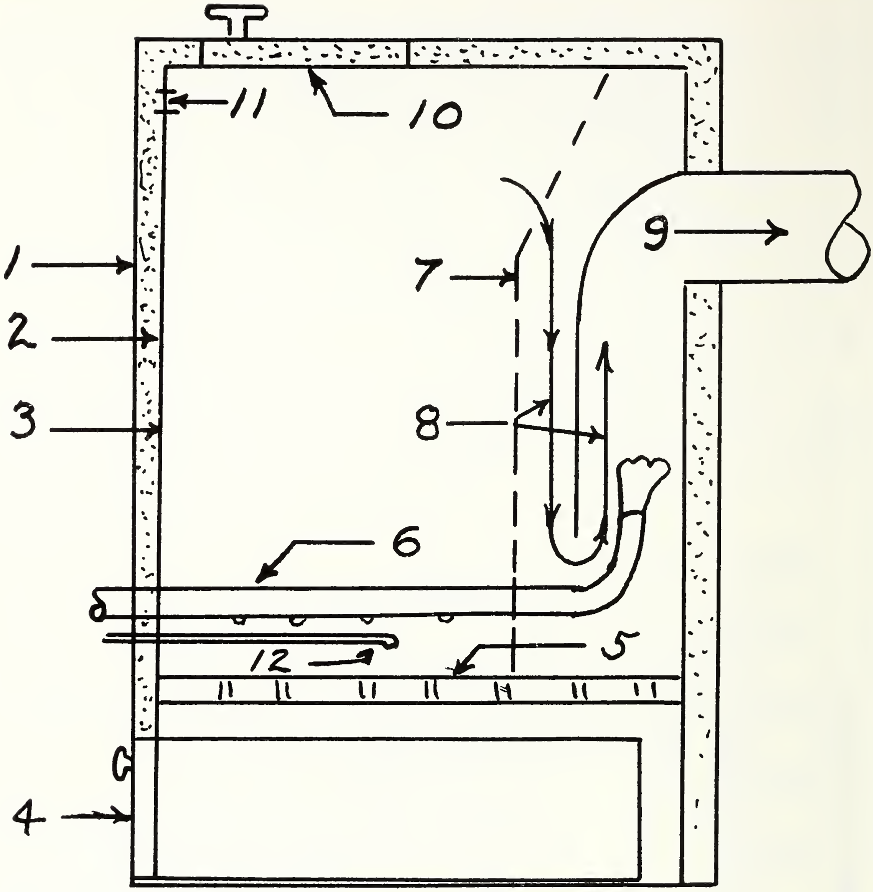
*__Standard Test Charge:__ Type D

1. 7 oz. White Potatoes (sliced)
2. 3 oz. Cabbage (3/4" cubes)
3. 2 oz. Oranges (4 unpeeled 1/8 segments)
4. 2 oz. Bread (white half slices)
5. 2.4 oz. Rice
6. 1 oz. Beef Suet (3/4" cubes)
7. 2.6 oz. Water
8. 6.6 oz. Corrugated Cardboard (6" squares)
9. 3.3 oz. Newspaper $22\frac{1}{2}$" x 33" sheets)
10. 3.3 oz. Wax Paper (12" wide x 3' lengths)

33.2 oz. Total Weight of Charge

* "Regulations for the Testing of Indoor Refuse Burning Equipment - Type D". __Ordinance Number 77-F__. Department of Buildings and Safety Engineering. City of Detroit, Michigan, May 3, 1956.

Fig. 88. Chart showing ignition-temperature cycle of a high B.T.U. input household incinerator.



1 - Outer Metal Shell
2 - Insulation
3 - Inner Metal Lining
4 - Ashpit Door and Pan
5 - Grate
6 - Primary Burner and Combined Afterburner
7 - Metal Retainer Plate - Perforated at Top
8 - Passage for Gases of Combustion
9 - Vent to Chimney
10 - Charging Door
11 - Overfire Air Ports
12 - Pilot Burner

Fig. 89. A schematic drawing of the after-burner type of household incinerator.

ment in the late 1950's of after-burner units that meet requirements of air pollution control ordinances.

The after-burner type is similar in appearance to other home incinerators. The principal difference is that the combustion chamber is baffled so that the gases of combustion from the primary chamber must pass down and under the baffle to reach the secondary chamber. A typical unit is shown in Figure 89. The gas burner is designed so that it discharges about one-third of its B.T.U. output into the primary chamber and about two-thirds into the secondary chamber.

Operation of after-burner type incinerators is similar to that of the high B.T.U. input type, but in general has a considerably greater heat input than the older types. This is because the major portion of the gas flame is discharged into the secondary chamber for smoke and odor destruction. Some units have timers on the main gas burner line so that the burner must stay on for at least two hours after it is ignited.

The products of combustion from the primary chamber go into the secondary chamber just above the grates. As they enter, they pass through the flame of the burner projecting into the secondary chamber. This flame increases the temperature and burns smoke and oily vapors.

In practice, when the main gas burner is ignited, the dry papers in the incinerator are ignited and the temperature of the gases leaving the unit rises rapidly. This increase in temperature is often less rapid than that of the high B.T.U. type, so the secondary burner is relied on for smoke and odor reduction. The temperature in the combustion chamber should rise to 1,200° to 1,400° F. to control odors. Most of the dry paper and similar materials are destroyed in about 10 minutes and the remainder of the refuse burns slowly.

After-burner incinerators may take almost twice as much time to burn a given amount of refuse as a high B.T.U. input unit does, even though the after-burner type may have about 25 per cent greater heat input. The main reason is that only about one-third of the heat input of the after-burner type is used to dry and burn the refuse. Two-thirds of the gas input is used to destroy smoke and odors. Additional fuel can be directed into the primary combustion chamber to speed up the combustion rate, but that, of course, increases the amount of gas consumed considerably. Also, if the burner is to be operated within the 1,200° to 1,400° F. range, the burner must have a refractory lining adequate to withstand such temperatures.

Evaluating Home Incinerators

The indoor type of home incinerator must be evaluated in terms of costs, safety, nuisances, and performance. Standards have been set up to measure some of these factors and tests have been conducted by several groups studying different phases of operation.

Costs

The cost of home incinerators that use auxiliary fuel varies considerably. Some are made so that they can be built into the base of the chimney when the house is constructed. Others, intended for basement installation, may be designed with exterior simplicity or may be as well finished as the best refrigerator or stove. Automatic controls, such as pilot lights and timers, add to the cost. The price of indoor incinerators varies from about $50 to $200, with after-burner types in the $100 to $200 range. Installation costs vary from $15 to $30, and again, costs for the after-burner type are usually in the upper range—from $20 to $30. Local wage scales affect installation costs, obviously. Assuming that a home incinerator lasts 15 years, annual capital costs range from $5 to $15.

Operating costs of home incinerators are determined by many factors, including the size of the household served; the cost of gas; the size of the burner; and to a large degree, particularly in the after-burner type, by operating practices. If the unit is charged and ignited manually and no auxiliary fuel is used, there is, of course, no cost for auxiliary fuel. On the other hand, if the gas burner is left on until the charged refuse is completely incinerated, auxiliary fuel may be required continuously, in some cases for as long as 10 to 15 hours. Manufacturers of some units have incorporated a "no cheat" timer in their burners so that once the burner is lighted, it cannot be shut off for at least two hours. Assuming an incinerator of this type with a burner input of 35,000 B.T.U. was operated every other day for at least two hours each time, more than 1 million B.T.U. of gas would be used in a month.

TABLE 26

ESTIMATED ANNUAL CAPITAL, INSTALLATION, MAINTENANCE, AND FUEL COSTS FOR THREE TYPES OF DOMESTIC INCINERATORS, 1959

Type of Unit	*Capital and Installation*[1]	*Maintenance*	*Auxiliary Fuel*	*Total*
Dehydrating	$12	$10	$24	$46
High B.T.U.	8-12	10	18	36-40
After-Burner	15	10	18[2]	43

[1] Assuming unit can be used for 15 years.

[2] May be much higher, depending on operating practices.

Maintenance costs for the dehydrating, the high B.T.U. input, and the after-burner types of incinerators are similar. The vent pipe for each is usually constructed of metal with a life expectancy of not more than five years. In most cases, the liner of the combustion chamber is sheet metal, which rusts and burns out. Charging doors warp from the heat of combustion when large amounts of combustibles are charged and need replacing. It is difficult to generalize on maintenance costs, but they probably are about $10 a year for 15 years.

Safety

There are two broad categories of safety factors: (1) those that affect the safety of the house directly and the occupants indirectly, and (2) those that affect the safety of the user directly and the house and its occupants only indirectly.

To burn garbage and similar refuse without producing odors, it is necessary to heat the gases in the incinerator to at least 1,200° F. and preferably 1,300° F., which is recommended. When large quantities of highly combustible refuse such as paper, excelsior, and wood are put into a home incinerator, the temperature of the gases of combustion may be as high as 1,500° F. A home incinerator is frequently connected to a conventional chimney designed to withstand temperatures of less than 1,000° F. Thus, to protect the chimney and reduce fire hazards, cooling air must be mixed with the products of combustion. This is done by installing a barometric damper.

The metal vent pipe and metal incinerator linings, however, must withstand red hot heat. Even the tops of some units become red hot, which in hazardous to the home unless safety precautions are taken. Ceilings above an incinerator vent pipe must be protected with suitable insulating material, such as asbestos millboard, if the clearance is less than 36 inches; flooring under the units must also be protected if it is combustible; combustible side and rear walls must be protected if they are less than 18 inches from the incinerator.

Surface temperatures of an incinerator are also important from a safety standpoint because there is always the danger that occupants of the house will touch hot surfaces.

Since some of the refuse put into an incinerator is explosive, provisions must be made for explosion relief in the primary chamber. That can usually be done by constructing the charging door so that it is self-opening and self-closing.

The greatest danger to the user of a home incinerator is flashback, which can only be countered through education. When the unit is charged with a large amount of combustible materials, such as papers, and then ignited, the fuel supply exceeds the air supply by a considerable amount. If someone opens the charging door too soon after the refuse is ignited, there is considerable danger of flashback as fresh air reaches the burning paper. Flames coming through the door are hazardous, of course, to people and property.

Nuisances

It is difficult to measure the nuisance potential of a home incinerator. Because of the difficulty of maintaining a flue gas temperature of at least 1,200° F. continuously, offensive odors may be produced when garbage and similar materials are burned. But an incinerator can easily be tested for odor creation by operating it so that at least part of the flue gases are discharged into a room where they can be smelled.

Odors can sometimes be detected if there is an insufficient stack draft. If smoke leaks from around the edges of the charging door, strong odors are usually present. Operating an attic cooling fan without opening a window produces a back draft and causes combustion gases from the incinerator to go through the house. The odors under such circumstances may be no different from those discharged from the top of the chimney but they are much closer.

The chances of odors becoming a nuisance outdoors are also hard to determine. The products of combustion are discharged from the chimney, a considerable distance above the ground. If the top of the chimney is also above the roofs of surrounding houses, the chances of odor nuisances are reduced a great deal. If the chimney top is lower than neighboring houses, however, the neighbors can expect odors frequently, especially if prevailing winds blow from the incinerator towards their houses. Actually, it is unusual when odors from a home incinerator settle so quickly that they can be detected on the user's property. Usually smoke and odors travel 100 feet or more before they settle to the ground, even under adverse atmospheric conditions.

It is possible for the user of a home incinerator to minimize or practically eliminate odors by using care and judgment in charging the unit; using it when weather conditions, particularly the wind direction and velocity, are right for burning; allowing the gas burner to run until all refuse is destroyed to prevent smoldering; and learning techniques for getting good combustion. Whether it is reasonable to expect such careful operation from many householders is a matter of conjecture.

A few incinerators in a neighborhood may be an occasional nuisance to some residents. But if everyone in an urban neighborhood has an incinerator, the potential for nuisances is multiplied; thus the widespread use of incinerators should be avoided unless the design and operation of them are carefully controlled.

Considerable smoke, condensible tars, and greases may also be emitted during the operation of a home incinerator. Sunlight reacts with the discharged gases to form more troublesome gases (as demonstrated in the Los Angeles area with smog). The volume of particulate matter and gases coming from a single house chimney is small, however, and therefore is not usually detrimental, at least in rural areas. Since the condensible tars, greases, and smoke are end products of incomplete combustion at low temperatures, it is possible to reduce them by using skill and judgment in charging and firing the incinerators and by using after-burners.

To alleviate fly ash and particulate emissions, suitable controls must be built into the incinerator. High air and gas velocities in the furnace and in the chimney stir up light particles and carry them in the air stream into the chimney discharge. The use of subsidence chambers to reduce these gas velocities is most helpful but, of course, increases costs and the amount of floor and roof space required.

Meeting Household Needs

To be useful, a home incinerator must burn refuse almost as quickly as it is produced—at least without having to store it. The dehydrating type has a fixed B.T.U. heat input and therefore its burning rate is fixed. If there is more wet refuse than the unit can dry and burn, the unburned residue accumulates on the grates until the incinerator is completely filled with unburned garbage. The high B.T.U. input incinerator and the after-burner types more nearly meet family needs because they can be operated sufficiently long to insure that the refuse is completely destroyed each time the incinerator is used.

Effect on Municipal Disposal Costs

Elimination of or reduction in the amount of refuse collection services in a city does not necessarily reduce costs of refuse disposal of the householder. If the elimination of municipal services is dependent upon purchase, operation, and maintenance of home incinerators and garbage grinders but the municipality must provide other special facilities to handle the increased sewage wastes, the householder may ultimately pay considerably more than he would for conventional municipal services. Of course, if all combustible refuse, including garbage, is burned in back yard incinerators without the use of auxiliary fuel, such is not the case. While this latter disposal method is cheap, it is neither sanitary nor conducive to good neighborhood relations.

There are many local conditions that must be considered whenever comparisons are made of disposal systems. Not the least of these are costs, which vary with the many needs of communities. Frequency of collections, types and locations of containers, types and quantities of refuse acceptable for collection, types of collection equipment, size of lots, disposal methods, and geographic location are primary factors in determining municipal costs. For example, in urban areas the cost to the householder of collecting and disposing of combustible refuse may vary from $15 to $35 a family a year. On the other hand, if a householder provides and maintains his own disposal facilities, the cost may vary from $16 to $50 a family a year.

Perhaps the most convenient way of disposing of refuse—but probably at the highest cost—is the use of both a home garbage grinder and a home incinerator. But the combination of an incinerator and a garbage grinder does not solve all disposal problems. Some type of collection and disposal service is still required for ungrindable, noncombustible solid wastes; for ashes and residue from domestic incinerators; and for bulky wastes that neither of the two disposal units can handle.

In cities that have an efficient, frequent refuse collection system, the home incinerator is a luxury and convenience for the housewife. Thus cities that have adequate or better collection and disposal systems may evaluate home incinerators differently from cities that do not. They also are in a better position to determine the over-all effect of home incinerators on the community and on the collection and disposal systems, including costs.

Effect on Municipal Disposal Practices

In cities where central incineration is the major method of refuse disposal, widespread use of home incinerators may have a considerable effect on the efficiency and efficacy of central incineration. The destruction of the easily burned paper, wood, crates, and similar materials in the home may reduce the "fuel" content of the remaining solid wastes that go to the central incineration plant to a point where auxiliary fuels, special designs, and special operating techniques are required in the plant, increasing the cost of central incineration considerably.

On the other hand, if sanitary landfills are used as the major disposal method, on-site incinerators, if properly used, not only reduce the putrescible components of refuse taken to the fills but also reduce the total amount of refuse that must be disposed of, thereby decreasing the nuisance potential and the amount of land required for fills.

Municipal Regulation of On-Site Incinerators

Several types of ordinances have been adopted by municipalities to regulate home incinerators or some factor in their use. Some ordinances prohibit or require incinerators; some regulate design, construction, installation, and performance; and some control air pollution from incinerators.

Most incinerator ordinances protect against unsafe construction and air pollution, but to be effective an ordinance should also cover other aspects of design, installation, and operation, and should require tests and licensing. An incinerator ordinance has other benefits, too: all installations are inspected, which makes for greater safety; and a list of incinerators approved to burn various types of refuse eliminates false claims such as "no odor," "complete, rapid combustion," and so on.

Prohibiting or Requiring Installation

Obviously, if a city prohibits the use of on-site incinerators there is no need for other regulations. Some cities require incinerators for new construction, however, as a means of reducing and eventually eliminating the combustible wastes the city collects.

Design, Construction, Installation Standards

The design, construction, and installation requirements are easiest to understand and agree upon. For the most part they are intended to keep incinerators safe and prevent air pollution. While a great deal of research is still to be done in this field, it is generally agreed that design and construction that permit vermin infestation, require excessive maintenance, or are dangerous to the user are not acceptable.[1]

Most ordinances specify chimney height and construction, flue size, draft control, distances from incinerator to combustible walls and ceiling, piping, gas connections, and other factors.

The public's concern with air pollution has had a definite effect on design and construction of home incinerators. The problem of designing one to meet modern air pollution control laws is basically one of producing combustion temperatures sufficiently high to completely destroy all odorous gases inside the unit. Accordingly, the incinerator must be constructed so that it can withstand the high temperatures required, retain the products of combustion for a sufficient time to assure complete combustion, and satisfactorily control the emission of fly ash.

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[1] See Appendixes E and F for approved standards for design, construction, and installation of domestic incinerators.

Operating Standards

Although many ordinances include broad standards for operating home incinerators (operated so as "not to create a nuisance," "fly ash discharge is not to be excessive," and so on), no rigid tests have been developed to determine performance characteristics of various incinerators. Most ordinances do require that instructions for igniting and shutting down the incinerator be put on a permanent rust-resistant plate fastened to the unit where it can be read easily.

Actually, the development of performance standards is not particularly difficult technologically, but the capital, operating, and maintenance costs of a unit designed and operated to meet such performance standards under all conditions probably would be considerably greater than most householders are willing to pay.

Air Pollution Control

Provisions in air pollution control ordinances that are supposed to regulate incinerators are much more difficult to write and administer than other types of incinerator regulations. Since atmospheric and other conditions vary from city to city, each city must develop its own control provisions.

Odor is the most important factor that must be controlled, but since no method has been developed to measure odors scientifically, the human nose must be relied upon. And there are those who say that it is noticeable that the offensiveness of an odor decreases in proportion to the financial gain from an odor-producing business.

Combustible refuse produced in a household can be classified into at least four groups on the basis of the amount of odor and smoke produced when it is incinerated.

1. Class A refuse: wood, paper, cardboard, and other materials that when incinerated do not usually produce excessive smoke or offensive odors.
2. Class B refuse: rags, rubber, leather, plastics, lint from vacuum sweeper bags, and similar materials that are not in themselves odorous but which often cause offensive odors when burned at low temperatures.
3. Class C refuse: food wastes resulting from preparation and use of foods in the home, normally known as garbage.
4. Class D refuse: grass clippings, weeds, leaves, brush, and similar materials.

Wood, paper, and cardboard—Class A refuse—does not usually cause offensive odors when burned at relatively low temperatures in a home incinerator. If an incinerator is properly charged and ignited, the amount of smoke emitted will usually be acceptable.

The inclusion of Class B refuse with Class A refuse changes the problem. Rags and leather burned at low temperatures produce offensive odors. Burning rubber at low temperatures produces both strong odors and dense black smoke.

A home incinerator that can burn Class A and Class B refuse without creating odors can probably burn garbage. Because of the difficulty of burning garbage without creating odors, however, many ordinances regulate the kinds of food wastes that can be incinerated.

Class D refuse creates odor and smoke problems if it is burned in a home incinerator. However, it is unlikely that anyone carries yard wastes into the house for disposal.

Testing and Licensing

Classification of refuse is also necessary if incinerators are to be tested and licensed on the basis of what kinds of refuse can be burned in them satisfactorily without producing odors, smoke, and fly ash.

Manufacturers, distributors, and salesmen, as well as others who are interested, are usually permitted to watch the tests made by licensing authorities.

In recent years the quantity of garbage included in a standard test charge has been reduced for home incinerators, which has been justified on the basis that each year the average family produces more combustible rubbish but less garbage. The primary purpose of the tests, however, is to determine the air pollution potential of a given incinerator. Since air pollution results from not only usual conditions but also from unusual ones, test charges should be used that duplicate as closely as possible the unusual: garbage and refuse from large dinners or canning, for instance. If an incinerator operates well when there is an unusually large amount of garbage, it is almost sure to operate well with normal amounts.

Upon satisfactory completion of tests, an incinerator is certified as to the types of materials for which it may be used. A permanent metal plate should be fastened to the unit stating exactly what kinds of refuse can be burned in it.

INCINERATORS FOR COMMERCIAL ESTABLISHMENTS

The refuse incineration needs of commercial establishments such as stores, small manufacturing plants, and restaurants vary greatly. A small neighborhood shoe store, for example, may have only about two bushels of waste paper and cardboard a day; a large supermarket may produce several tons a day.

Municipal refuse collection systems are not ordinarily set up for the type of service required by large stores; they are primarily intended for residential areas. But commercial establishments usually have limited storage space for refuse; furthermore, some of their storage practices are hazardous. Nor are the services of private collectors always a good solution. Such services are expensive in some cities and sometimes are too limited as to time and frequency of collections.

All of these factors make on-site disposal of refuse a desirable solution to the problems of commercial establishments. If other disposal methods are expensive and only partially meet the need, the costs of a satisfactory incinerator are almost insignificant.

Many small stores use incinerators that are similar to but larger than the high B.T.U. input home incinerator. Unfortunately, the operational problems are also similar to those that must be solved to achieve satisfactory performance with domestic incinerators. However, since each store produces much the same type of refuse each day, it is somewhat easier to establish good operating procedures than it is at home.

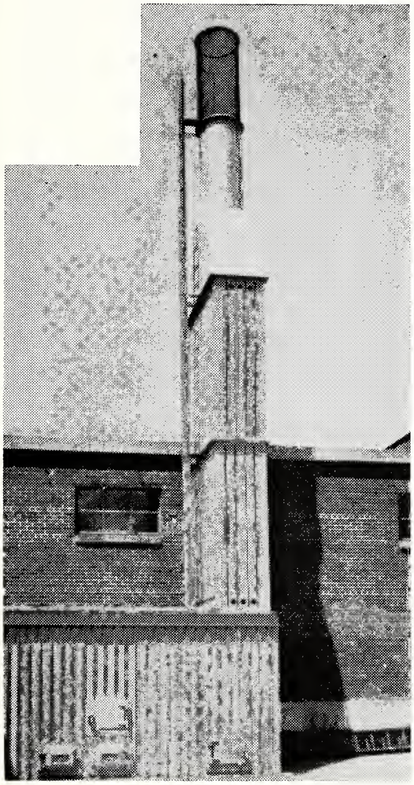


Fig. 90. An incinerator used in a large supermarket in Cincinnati has a rated capacity for burning 1,200 pounds of dry refuse in an hour.

It is usually not difficult to incinerate satsifactorily in those businesses in which only waste paper and cardboard are burned and if there are no residences within 75 feet of the stack outlet. There are many incinerators that can burn materials of this type satisfactorily, since they do not produce offensive odors while burning and quickly burn to ash if properly charged and exposed to sufficient heat and oxygen. The size of the charge must be limited, however, so that the primary combustion chamber is not overloaded and auxiliary fuel is not necessary for smoke destruction. A subsidence chamber also should be provided or the combustion chamber must be large enough to reduce gas velocities so that fly ash is minimized.

Food stores, supermarkets, restaurants, produce terminals, and similar businesses have an entirely different and much more serious incineration problem. They must burn highly combustible refuse, as well as food wastes, which contain from 50 to 90 per cent water. The problem is to design an incinerator that will successfully burn both types of refuse.

The largest portion of the refuse from a supermarket, for instance, consists of cardboard boxes, wood boxes, and paper. This material is light, bulky, and readily combustible, although thin wood boxes are almost impossible to burn without producing smoke. An incinerator for this type of refuse should have a large charging door, a large primary combustion area, an ample supply of air, a large settling chamber, and a low flue gas velocity, as well as an after-burner. The other part of the refuse is vegetable wastes, such as lettuce and celery leaves, which do not have enough heating value to burn themselves. Thus auxiliary fuel must be used to maintain a temperature of from 1,200° to 1,400° F. for the gases leaving the unit. Dehydration and combustion of these materials is slow, so to conserve heat only a small amount of air should be used. Frequent agitation of the refuse on the fuel bed is desirable to close up the holes and to increase the burning rate. Because of the lower air requirements for combustion, the gas velocities through the unit are lower and fly ash discharge is considerably less until the grates are almost bare.

The incinerator that will burn both types of refuse successfully must be a compromise that permits operation at both extremes or any place between extremes. But doing a satisfactory job depends to a large extent on the way an incinerator is operated, and unfortunately the unit that eliminates all skill and judgment on the part of the operator has not yet been built.

Costs

Commercial incinerators vary in price according to size. A doctor may have an incinerator in his office to dispose of waste paper that costs about $100. But a warehouse for a supermarket chain may require one as large as those used by small cities, which cost more than $50,000.

Operating costs vary considerably with the type of installation and the materials burned. Almost all commercial incinerators must use auxiliary fuel. Gas consumption depends upon the size of the burner to some extent, but the greatest variable is the judgment of the operator who determines the length of time the gas is used.

Maintenance costs for commercial incinerators are usually high. Most incinerators are subjected to high temperatures because of the quantities of paper and cardboard burned. Intermittent operation and rapidly rising and falling temperatures shorten the life of brick work, vent pipes, and chimneys.

Nuisances

Commercial incinerators that are improperly designed or improperly operated are a source of smoke, odor, and fly ash nuisances. Many cities have ordinances controlling their installation. Usually the regulations require adequate temperatures for odor destruction (which vary from 1,200° to 1,500° F.), heavy duty construction to withstand continuous temperatures as high as 2,000° F., settling chamber gas velocities from 5 to 15 feet per second, drying hearths for wet materials, secondary air, auxiliary fuel burners, and an adequate chimney.

The data supplied when applying for a permit to install a commercial incinerator indicate only in a general way what operating results may be expected. Many of the factors are so interdependent that a series of tests is often necessary to determine the limitations of a given incinerator.

Incinerators for Industry

Many factories and industries incinerate refuse and trade wastes in small or medium size incinerators on the premises. A study of the kinds of wastes to be burned usually indicates in a general way the procedures that must be followed to get satisfactory combustion.

Trade wastes that produce strong odors or heavy smoke are difficult to burn in a small incinerator. It is usually cheaper to dispose of them by taking them to a landfill or municipal incinerator. If they are burned in a small incinerator, however, an operator should be present the entire time to keep the combustion temperatures above 1,300° F., to limit the size and frequency of the charges, to provide sufficient air for complete combustion, and to regulate the draft properly. A small incinerator must be well designed and well constructed to meet these requirements; operating costs will be relatively high.

Hospital Incinerators

Hospitals must have sanitary disposal facilities readily accessible at all times. The disposal problem in hospitals is complicated because the refuse usually has a high garbage and moisture content and the anatomical wastes are malodorous and germ-ridden. At the same time that the need for nuisance free disposal operations is the greatest the tolerance for a badly operated disposal system is the least. So when on-site incineration is used, the equipment must be correctly designed and operated. Flue-fed incinerators should never be installed in a hospital. The usual practice is to use an incinerator consisting of a furnace and combustion chamber, although large hospitals may use one similar in design to a small municipal incinerator. Use of auxiliary fuel is essential. Most important, regardless of the size of the hospital, are prompt and thorough burning and a minimum of storage.

Some hospital refuse does not burn readily and close supervision is needed during burning. If insufficient auxiliary fuel is used, odorous gases

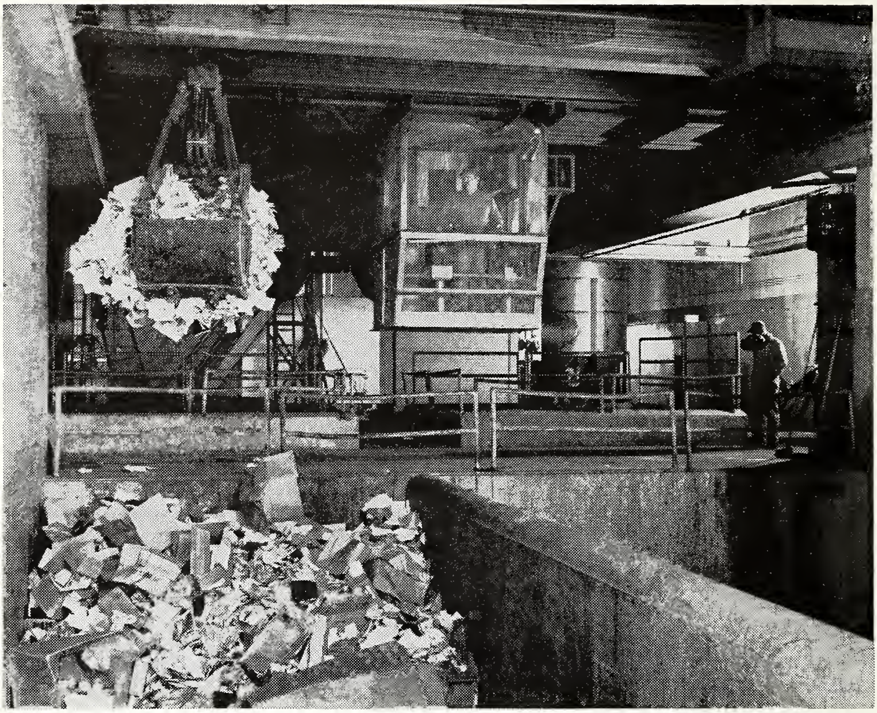


Fig. 91. Some hospital incinerators must burn a large amount of refuse. The incinerator at the National Institutes of Health at Bethesda, Maryland, is of the pit and crane design; gas scrubber equipment is at the right.

are sure to be present. Frequent agitation of the refuse on the fuel bed is also necessary when burning hospital refuse; but since hospitals are usually understaffed they often do not give incinerators the attention they need.

Hospital incinerators are expensive. A well designed one with provision for adequate combustion temperatures and fly ash control costs about the same as a municipal incinerator. Furthermore, because of the nature of some of the refuse burned, hospital incinerators cannot be designed for economic automatic operation; one employee must be responsible for its operation. It may not be a full-time job, but it is necessary to give almost continuous attention to the task during burning.

Operating room wastes, experimental animals, and cadavers create problems different from other hospital refuse disposal problems. They are ordinarily disposed of in a separate incinerator designed especially for this purpose. The usual installation consists of a furnace with auxiliary fuel burners and a combustion chamber heated by auxiliary fuel and equipped with after-burners to insure that the gases leaving the chamber are heated to at least 1,300° F. A washer for reducing the fly ash to acceptable levels may also be provided.

Cadavers and operating room wastes are put into the furnace proper.

TABLE 27

AVERAGE DAILY PRODUCTION OF HOSPITAL WASTES FOR 29 HOSPITALS WITH AVERAGE OF 224 PATIENTS[1]

Type of Waste	*Average Weight per Capita*[2] *(Lbs. per day)*	*Average Volume per Capita*[2] *(Cubic ft. per day)*	*Average Weight per Patient (Lbs. per day)*	*Average Volume per Patient (Cubic ft. per day)*
Garbage (Specific weight: 53 pounds per foot^3)	1.86 (8)[3]	0.035 (15)	3.28 (8)	0.064 (15)
Noncombustibles (Specific weight: 9.24 pounds per foot)	0.83 (5)	0.090 (17)	1.10 (5)	0.111 (17)
Combustibles (Specific weight: 4.85 pounds per foot)	1.67 (5)	0.344 (21)	2.61 (5)	0.521 (21)
Surgical			0.11	
Autopsy			0.03	
Total	4.36	0.469	7.13	0.696

[1] Computed from weekly waste production data in a report of the Committee on Hospital Facilities, Engineering and Sanitation Section, American Public Health Association, November, 1955.

[2] Average equivalent population of 29 hospitals sampled was 393.

[3] Figures in parentheses indicate number of hospitals included in averages.

The after-burners and the combustion chamber burners are ignited and the brickwork heated up until the gases leaving the chamber reach 1,800° F. The washer is then started and the burners in the furnace are ignited. By preheating the combustion chamber, complete odor destruction is assured.

The costs of operating such incinerators are high because it is necessary to preheat the combustion chamber and maintain high furnace temperatures. The brickwork maintenance costs are correspondingly low, however, because the incinerator is fired infrequently. The only routine servicing required is one that keeps auxiliary fuel burners and gas temperature indicators operating satisfactorily.

INCINERATORS FOR OTHER INSTITUTIONS

Other institutions are also confronted with refuse disposal problems. When located in a large city, institutions usually use municipal services, but if they are in outlying or rural areas, as is often the case, it may be necessary to use on-site disposal. Incinerators can be designed for satisfactory service in institutions because charging of the refuse can be controlled. Under no circumstances, however, should a flue-fed type of incinerator be used.

A typical incinerator in an institution consists of a furnace and a combustion chamber, which should, of course, be correctly designed. In many, no auxiliary fuel is used and so the operator has no means of controlling the temperature of the gases that leave the incinerator.

Many institutional incinerators cause air pollution problems. Some problems result from careless operation but usually they result from installing a "cheap" unit in the interests of "economy."

The cost of a suitable incinerator depends to a great extent upon the size of the institution and the type and quantity of refuse burned. Auxiliary fuel burners should be used to insure satisfactory combustion temperatures and odor destruction when necessary. The combustion chamber must be designed for low gas velocities to insure that fly ash is trapped or a wet collector must be used. Equipment meeting these requirements costs several thousand dollars. Operating costs vary with the size of the unit, the amount of auxiliary fuel required, and labor costs.

Apartment House Incinerators

Large apartment houses often have no refuse storage facilities; and the need for inexpensive refuse disposal facilities on all floors 24 hours a day led to the development of the flue-fed incinerator. It is the most desirable incinerator for this type of service, but flue-fed incinerators are heavy contributors to air pollution.

The flue-fed incinerator is basically a chimney with a charging door from a hall on each floor of the building. The furnace is directly under the chimney. A conventional flue-fed incinerator is shown in Figure 92.

The theory of operation is simple. Tenants take refuse to the charging door on their floor and drop it into the chimney. The refuse falls onto the grates and when they are full an attendant ignites the charge and the refuse is burned to ashes. The products of combustion pass over the refuse and up the chimney. In a few installations the chimney is divided by a wall so that one side is used for the refuse and other for passage of gases. The ashes are removed and the incinerator is ready to receive more refuse.

In practice, a flue-fed incinerator is a good example of poor combustion practices. Almost all of them have only a single chamber. Large amounts of wet refuse collect in the incinerator and when it is ignited, it creates a great deal of smoke, odor, and fly ash. The operator seldom has control over the charging, little regulation of the draft or air supply, and no auxiliary fuel for temperature regulation.

Flue-fed incinerators can be designed for fairly satisfactory operation, although smokeback problems usually cannot be avoided. Studies show that a secondary combustion chamber is essential for smoke, odor, and fly ash control. Auxiliary fuel is necessary to maintain temperatures above 1,300° F. in the combustion chamber, which insures destruction of smoke and odors. If charging doors on each floor are locked during burning, flashbacks are eliminated and wet refuse cannot be dropped on a new

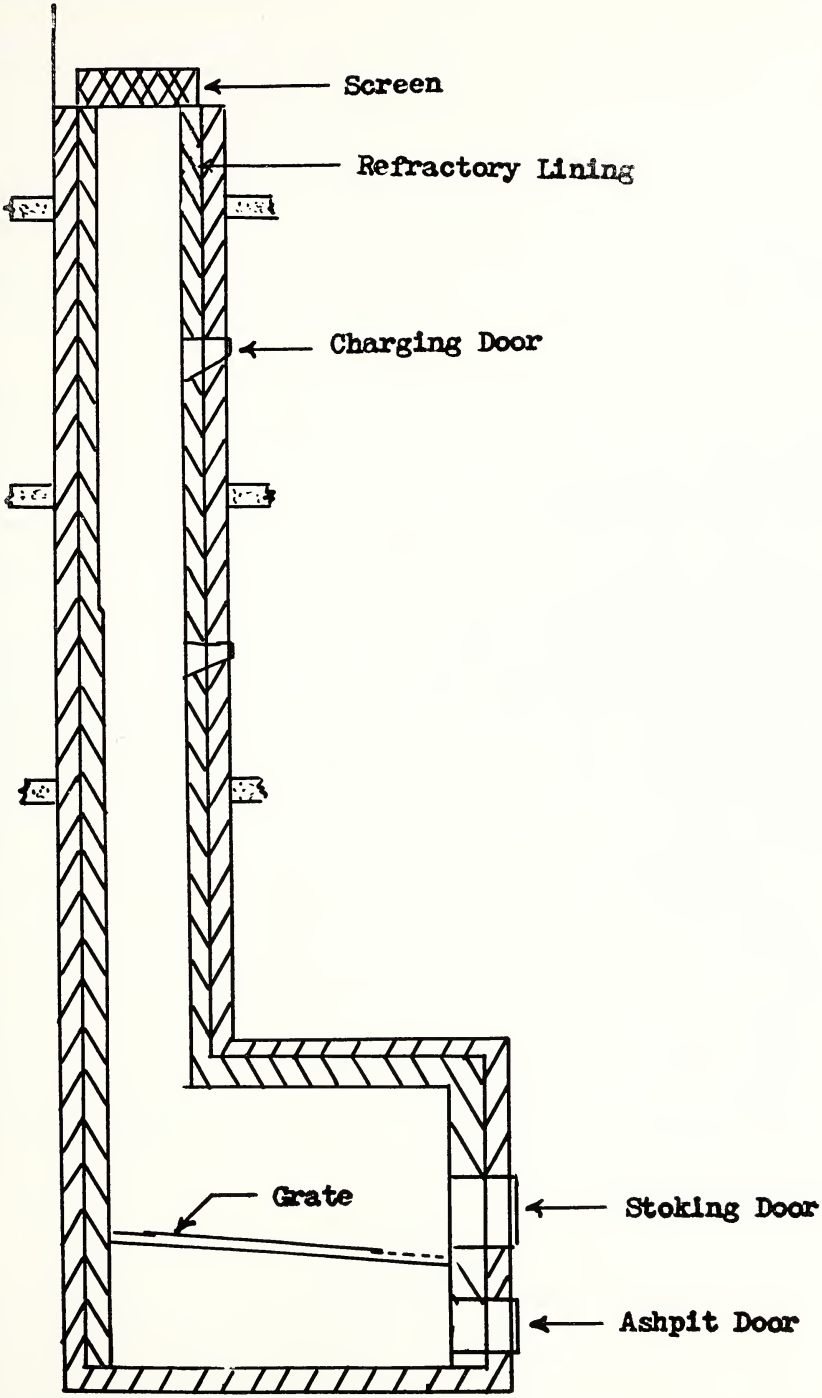

Screen
Refractory Lining
Charging Door
Grate
Stoking Door
Ashpit Door

Fig. 92. A schematic drawing of a flue-fed incinerator, the type frequently used in apartment buildings.

fire and smother it. The charging doors can be locked either manually or electrically.

The best method of controlling the refuse in the incinerator is to build a separate charging chute with a gate at the base so that the refuse is stored in the chute instead of in the furnace. This gives the operator some control over the fire. He is able to drop the quantity of refuse desired into the unit after the fire has reached the correct temperature, and he can rake refuse forward onto the burning grates as required. Gas burners that are properly located and of sufficient size make it possible to maintain adequate temperatures for combustion. However, the use of the flue as a rubbish container creates fire and smoke hazards.

The fly ash problem can also be solved satisfactorily. The wire mesh screen that is required on the chimneys of all flue-fed incinerators is of little value except for large pieces of paper. Barometric dampers for controlling the draft help produce reasonably stable gas velocities, and wet sprays can reduce the fly ash to acceptable levels.

In old buildings, especially where there is not enough space to install a secondary chamber, settling chambers built on the roof have been successful. Here the gases slow down, are forced to make several turns, and then pass out to the chimney.

Flue-fed incinerators, because of their convenience, can be expected to be legally acceptable for many years in some communities. Increasing consciousness of air pollution problems, however, is expected to force changes in design and operation. New buildings with adequate size multiple-chamber incinerators, controlled charging of materials, large

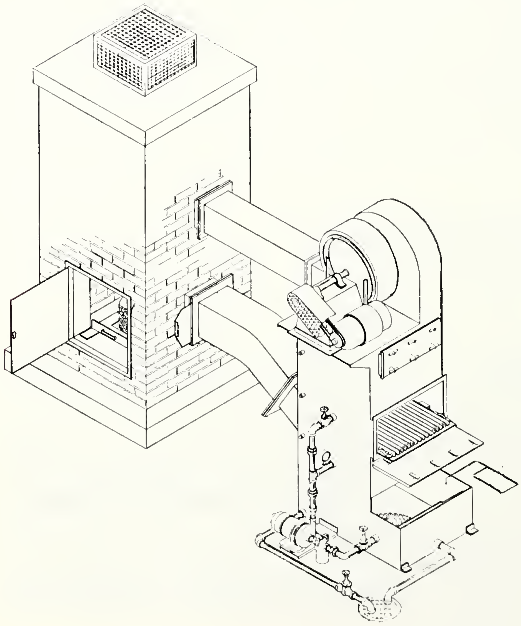


Fig. 93. Gas scrubber for a flue-fed incinerator.

auxiliary fuel burners, positive draft control, and adequate fly ash removal equipment will not add to air pollution.

Air pollution from old flue-fed incinerators is much harder to control. The cost of modernizing old incinerators is prohibitive in many cases because space is inadequate for the amount of equipment needed. The best possible operation of the incinerator is a compromise in such cases.

As a rule, however, installation of flue-fed incinerators should be discouraged. The need to inspect them constantly is a problem for any city. Failure to enforce operating standards usually results in smoke, odors, and fly ash over a considerable area.

Incinerators for Special Purposes

There are many industrial salvage and waste disposal operations that require special incinerators. Those designed to burn automobile bodies and those that burn combustible demolition debris are sufficiently widely used to warrant consideration here.

Automobile Bodies

An automobile body contains a considerable amount of high-grade scrap metal that can be sold at a profit if it can be salvaged economically. However, it also contains large amounts of upholstery, plastics, undercoating, grease, paint, and paper products, none of which is acceptable to steel mills.

The practice in the past was to burn automobile bodies in the open after spraying them with fuel oil. This produced large clouds of dense black smoke and strong odors. The method is so obnoxious that most cities prohibit it. However, the cost of labor is so high that if objectionable materials must be stripped from cars by hand, salvage is uneconomical.

Large continuous-flow incinerators that can burn 100 to 200 car bodies in an eight-hour day have been developed, however, to meet the need. They consist of a long rectangular furnace equipped with a conveyor that drags a car from a loading platform on one end to a discharge platform on the other end. As the car body enters the furnace, it passes oil or gas burners that ignite the combustible materials. The burning continues as the car moves through the furnace and it is completed before the car reaches the discharge end. Before leaving the furnace, the car is sprayed with water, which puts out any remaining fire and washes and cools the scrap metal.

The furnace chamber is maintained under controlled negative pressure so that all products of combustion must pass through smoke and fly ash control equipment. This may consist of after-burners to insure complete combustion and wetted baffles or electrical precipitators to remove fly ash and carbon particles. Units of this type can be operated satisfactorily without nuisance in any city and meet most conventional smoke abatement ordinances.

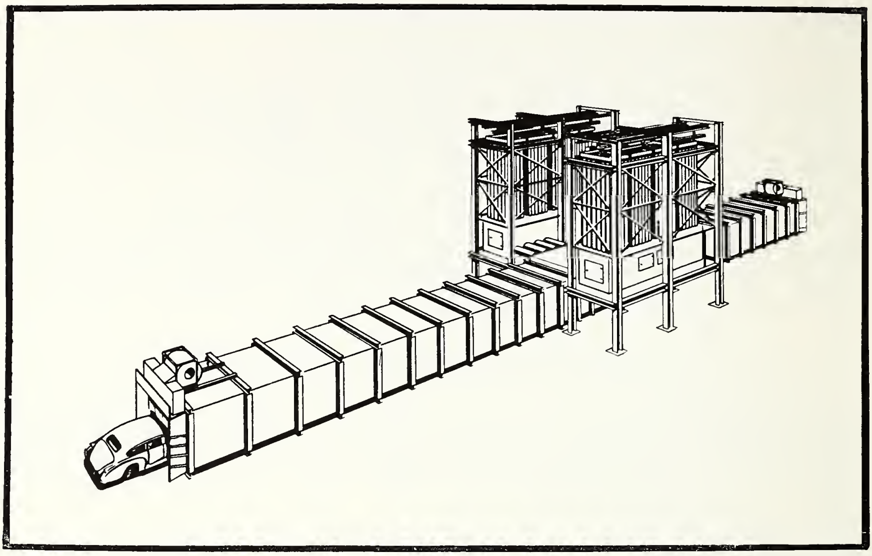


Fig. 94. This incinerator, especially designed to burn combustibles from automobile bodies so that the metal can be salvaged, can handle 15 to 20 cars an hour. It uses the electrostatic precipitation method of controlling particulate discharge.

Demolition Debris

Many cities are engaged in extensive slum clearance and other building and rebuilding projects. Most of the buildings torn down contain a substantial amount of combustible materials such as wood and tar paper. If this material is burned in open fires, it produces smoke, odors, and fly ash. If it is burned in a conventional municipal incinerator, it must first be reduced to acceptable size by cutting or hogging.

The need to destroy such material at the source with a minimum of nuisance has led to the adaptation of the old sawdust burner to the house wrecking field. The incinerator is a tepee-shaped, single-walled, steel burner that has a large opening at ground level for introduction of waste materials and a small opening at the top to discharge products of combustion.

At best this method is controlled, open burning. No attempts are made to use auxiliary fuel to maintain satisfactory temperatures. In fact, the very construction of the incinerator requires that temperatures be kept reasonably low to protect the steel casing. The fly ash discharge is greater than most air pollution ordinances permit. However, since the burning period is short, it is a fast and economical method of destroying a great deal of combustible refuse.

Probably a more satisfactory way of disposing of construction and demolition debris and large tree limbs, palm fronds, and banana stalks is to use large hoggers to shred them to a size that can be burned in central incinerators. Although further study and development of the method is needed, it is being used successfully in a number of places.

The Future of On-Site Incineration

Almost all large cities have adopted ordinances prohibiting use of on-site incinerators that produce objectionable quantities of fly ash, which probably will result in improved design and operating practices for such incinerators.

With increased concern over air pollution, ordinances that require installation of on-site incinerators are probably a thing of the past, at least until satisfactory designs and operation can be assured under normal conditions. Instead, more ordinances that limit and control incinerator installations can be expected. Future ordinances will probably prescribe in exact detail the installation procedures, chimney limitations, safety requirements, and operation of the incinerators. More important, the types of refuse that can be burned will be strictly limited to assure odor and fly ash control.

A "model" incinerator ordinance that can be adapted to local conditions by most cities is badly needed. At the present time each city must more or less develop its own regulations. A great deal more knowledge of the problems and solutions is necessary, however, before a model ordinance can be written.

Studies to determine suitable grate areas, furnace volumes, and gas velocities for various types of on-site incinerators are needed. Tests are are required to determine the most effective size and shape of combustion chambers and the best auxiliary equipment to assure odor-free burning and to control fly ash and gas emissions. The use of auxiliary fuel does not necessarily assure satisfactory operation and odor and fly ash control. Research is needed to determine how to use auxiliary fuel most effectively.

The increasing number of companies that manufacture, sell, install, and service on-site incinerators gives assurance of continued developments in this field; and the air pollution problem forces manufactures to meet more stringent requirements. But the criterion that will finally determine how extensively on-site incinerators will be used in the future is how well they can compete economically with other acceptable refuse disposal methods.

7 GRINDING FOOD WASTES

The disposal of food wastes by grinding—the process by which garbage is changed into small particles and flushed into the sewers—has been widely accepted in recent years. Eliminating garbage on the premises as it is produced is considered the ultimate in convenience and sanitation. The on-site grinder reduces the time garbage is stored on the premises to an absolute minimum.

The over-all benefits of garbage grinders to a community must be carefully evaluated, however. Grinders are useful but they do not eliminate the necessity for collection of most refuse. Garbage usually is less than 10 per cent of the volume of refuse collected. Yard wastes such as wet grass and weeds, which are not put in the grinder, can produce odors that are as obnoxious as those produced by garbage. Furthermore, not all garbage can be disposed of through a grinder; some must be stored for collection.

Garbage grinders are usually divided into three classes according to their use. Home grinders are exactly what the name implies. Commercial and institutional grinders are large units used in restaurants, hospitals, and food processing establishments such as a produce center or supermarket. Municipal grinders are even larger and are used to dispose of garbage collected by conventional means and taken to a central grinding station.

HOME GRINDERS

The millions of home garbage grinders already in use have become a symbol of convenience and sanitation to many housewives. It is obvious that their number will increase considerably in the future.

The grinder is located in the most convenient place for disposing of food wastes—in the kitchen sink. This is where food is prepared and the housewife decides which lettuce leaves will be eaten and which thrown away; it is the place where dishes and cooking utensils are stacked and where the housewife determines which leftovers will be thrown away. Thus the transition from food to garbage is rapid; and disposal by grinding is equally fast. The refuse is scraped into the grinder, a twist of the wrist locks the cover, a water faucet is turned on, and in a matter of seconds the garbage is ground and flushed into the sewer system.

Types and Safety Features

Because of the growing acceptance of home garbage grinders, there is an increasing number of companies manufacturing them. The units vary

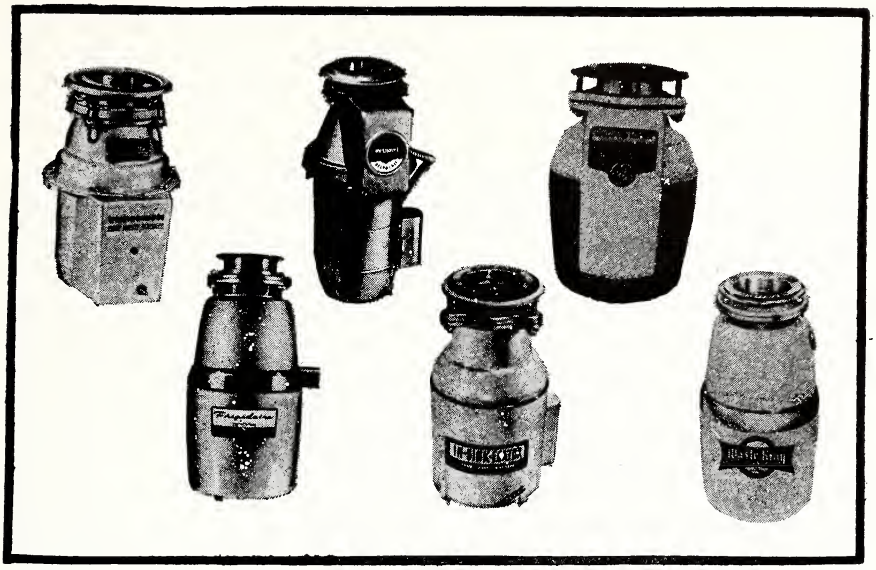


Fig. 95. There are many types and makes of household garbage grinders. Above are grinders made by Westinghouse, Hotpoint, General Electric, Frigidaire, In-sink-erator, and Given.

in appearance, size, and operation but the design principles are about the same. All are installed in the sink and are equipped with a refuse chamber that holds about a quart of garbage. Cutters, or shredders, are rotated at high speed by an electric motor. Cold water from the faucet is required to flush the ground garbage through the grinder and into the sewer system. (Cold water must be used so that grease will congeal before it enters the sewer system.)

A sink garbage grinder must grind the food uniformly fine. Large particles sometimes lodge in the drain pipes or settle in the sewers. Grinders vary considerably in this performance, depending on the design and manufacturer. It is desirable for a city to set up performance standards for size of grind and to require that the standards be met before a grinder can be installed.

There is considerable difference in safety features of grinders. Some have an electric switch that is actuated by locking the cover in place—a type that cannot be operated when the cover is open, thus making it impossible to get fingers in contact with the revolving shredders. If large quantities of garbage are ground in this type, however, it is necessary to stop the grinder to recharge it.

Some grinders have covers that are not interlocked with the electric circuit; others have an open top protected by rubber "fingers." Garbage can be put into these two types of grinders while they are running. But it is also possible for children to put their hands into the revolving cutters.

Any type of home grinder can be equipped with a water flow control switch that is operated by turning on the cold water faucet. When the flow reaches the desired volume, the grinder starts. This procedure insures an adequate flow of water before the grinder can operate and minimizes

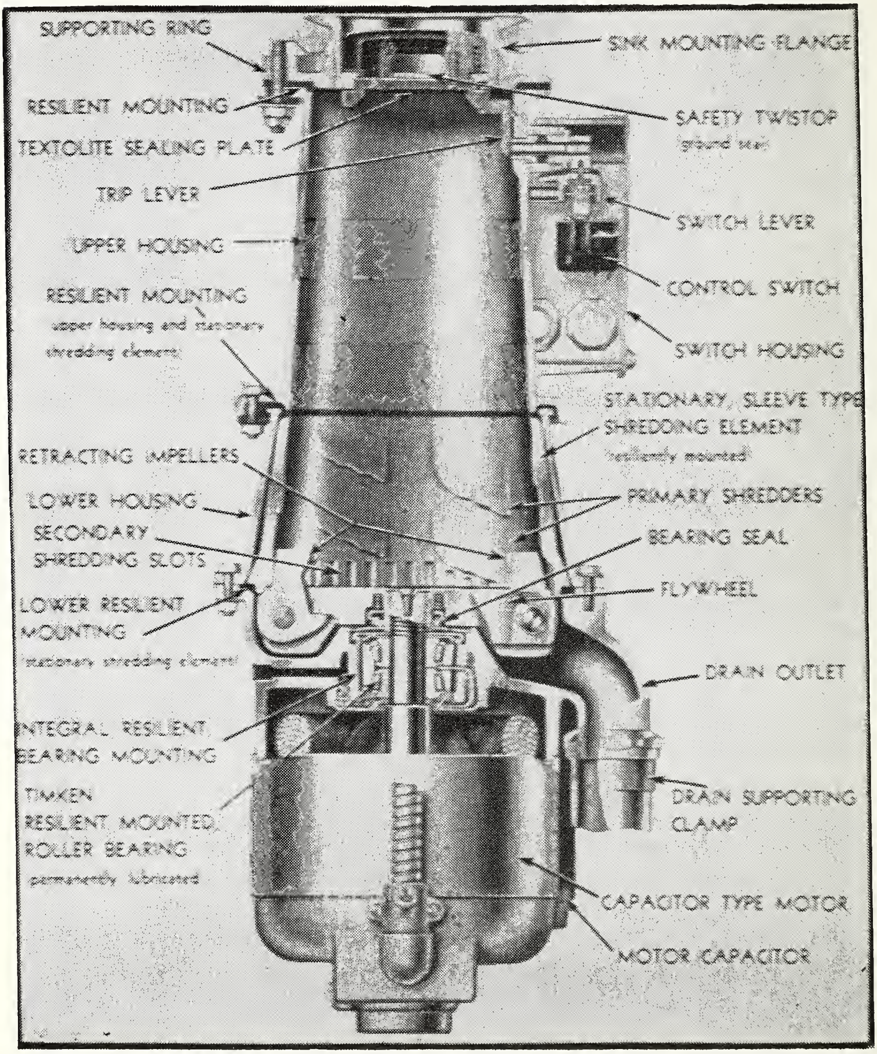

SUPPORTING RING
RESILIENT MOUNTING
TEXTOLITE SEALING PLATE
TRIP LEVER
UPPER HOUSING
RESILIENT MOUNTING
(upper housing and stationary shredding elements)
RETRACTING IMPELLERS
LOWER HOUSING
SECONDARY SHREDDING SLOTS
LOWER RESILIENT MOUNTING
(stationary shredding element)
NTEGRAL RESILIENT BEARING MOUNTING
TIMKEN RESILIENT MOUNTED ROLLER BEARING
(permanently lubricated)
SINK MOUNTING FLANGE
SAFETY TWISTOP
(ground seal)
SWITCH LEVER
CONTROL SWITCH
SWITCH HOUSING
STATIONARY, SLEEVE TYPE SHREDDING ELEMENT
(resiliently mounted)
PRIMARY SHREDDERS
BEARING SEAL
FLYWHEEL
DRAIN OUTLET
DRAIN SUPPORTING CLAMP
CAPACITOR TYPE MOTOR
MOTOR CAPACITOR

Fig. 96. A cross section of a household garbage grinder. This grinder has a top control that must be put into the sink opening and turned to the "on" position before it will operate. It is also equipped with a flow interlock valve, which prevents the motor from operating unless an adequate amount of cold water is running through the mechanism. Newer units are equipped with "anti-jam" devices; in some models the direction the blades rotate is reversed each time the unit is turned on.

the danger of plugging the drain lines with ground garbage. The switch increases the cost of the grinder, however, and so it often is not included.

Portable Grinders. Portable grinders do not appear to have sufficient advantages to justify their becoming important in the refuse disposal field. They are self-contained units that are placed in the sink and plugged into an electric outlet. Water from the faucet is used to grind and flush ground garbage down the sink drain.

Portable grinders are not widely used. They weigh about 21 pounds, so that it is difficult for a woman to lift them; and flushing garbage down a conventional drain also presents difficulties. They cost about what a low priced permanently installed grinder does, but they can be used in old houses where it is difficult and expensive to install permanent ones.

Effect on Municipal Services

Cities that permit or encourage the installation of home garbage grinders must plan for the changes that they require. The effects of the first few grinder installations are so insignificant that little thought may be given to what may happen when there are a lot of them. The need for additional water, sewer, and sewage treatment facilities can develop so rapidly that the problem may become acute before steps are taken to correct the situation. If a city has financial difficulties also, a satisfactory solution is even more difficult.

Water Supply. During grinding, water is used at the rate of 1.5 gallons a minute or between 1 and 2 gallons per capita per day. The installation of home grinders does not materially affect the municipal water supply (except in critical areas), since grinders increase the use of water by only 2 or 3 per cent.

The water supply does affect the use of garbage grinders, however. Units equipped with a flow control switch will not operate until a predetermined amount of water is flowing from the faucet. In areas where the water pressure drops appreciably during periods of heavy demand, it may be impossible to operate a grinder during some parts of the day. Elimination of the flow control switch does not solve the problem in such cases, because the water flow would probably also be insufficient to properly flush the drain lines. The result of insufficient flushing is clogged drains—an expensive and inconvenient problem to solve.

Sewers. Experience with domestic grinders shows that the admission of finely ground garbage to house plumbing does not clog it; in fact, there is a tendency for the garbage to keep the inside of the pipes clean.

Normal domestic sewage and most industrial wastes are so dilute that if there is an average of 50 per cent increase in the amount of suspended solids in sewage caused by citywide installation of garbage grinders, there will be little more deposition than under normal conditions. Therefore, if a sewer system is free of deposits, it is reasonable to expect that it will remain so after the addition of ground garbage. However, if a sewer system is inadequate to handle the deposition of sewage solids before there are many home grinders, the addition of ground garbage may in-

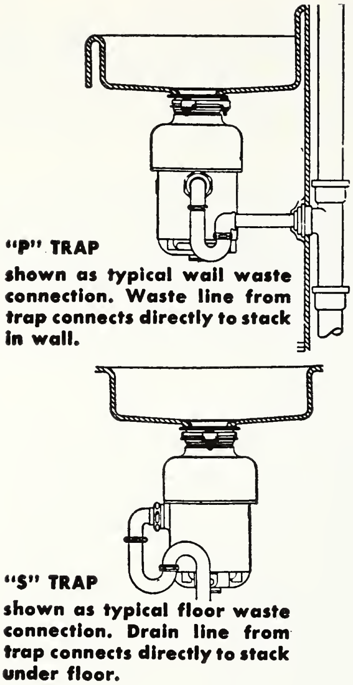

"P" TRAP
shown as typical wall waste connection. Waste line from trap connects directly to stack in wall.
"S" TRAP
shown as typical floor waste connection. Drain line from trap connects directly to stack under floor.

Fig. 97. Most domestic home grinders can be installed under any standard sink that has a 3½-inch drain opening.

crease the amount of deposition in some parts of the system a great deal. Furthermore, inasmuch as garbage is higher in volatile solids than sewage is, the volatile content of the deposits is increased, thus increasing the putrescibility and the likelihood of obnoxious odors. The frequency with which the sewers must be flushed is increased; if they are not, sewage reaching the treatment plant is more septic than normal.

Problems of this kind may warrant prohibition of home grinders. The blame should not be placed on the grinders or the garbage, however, but on the faults in the design or construction of the sewers.

There can be trouble in even well designed sewer systems with deposition of solids at the upper ends of laterals, where the volume of sewage is too small to maintain adequate flow, causing solids to become stranded along the pipe. If domestic grinders are installed in houses tributary to the upper ends of lateral sewers, such difficulties may be increased. Flushing is the only remedy.

Sewage Treatment Plant. If sewage is discharged into a stream or large body of water without treatment, the installation of home grinders does not increase the cost of disposal for the municipality. However, the practice of discharging raw sewage into water (except perhaps in some special cases) is a questionable one. It is only a matter of time before some sewage treatment is necessary for almost every community.

The effect of introducing ground garbage into a sewage treatment plant depends upon the method and point of introduction, the type of treatment plant, and the quality of effluent desired.

If all garbage were ground at the point of origin and flushed through the sewer system, the suspended solids content would increase by up to 100 per cent, with an average 50 per cent increase for any one system. The biochemical oxygen demand (B.O.D.) of the sewage will increase up to 65 per cent, with an average of 30 per cent. Ground garbage may increase the amount of grit in sewage by about 40 per cent where home grinders are used and by 80 per cent where central grinding stations are used. Grit tends to have a high volatile content and is potentially offensive.

In primary tank operation, the volume of scum and sludge can be expected to increase up to 100 per cent, partly as a result of the increase in suspended solids in the raw sewage and partly as a result of an apparent increase in removal efficiency caused by the addition of garbage solids.

Primary effluent may increase in suspended solids by 5 to 10 per cent and in B.O.D. by 15 to 30 per cent, requiring corresponding enlargement of secondary treatment facilities.

Increased facilities for sludge digestion, sludge handling, and digester-gas collection are necessary if ground garbage is added to either the sewage or the digester directly.

The introduction of ground garbage into the sewage system usually increases the treatment plant loading. If a treatment plant was built to handle future needs and is not operating at capacity, obviously expansion is not required. On the other hand, if the treatment plant is working at or near capacity before grinders are installed, it will be necessary to build additional facilities before there are many grinders.

The cost of processing ground garbage in a treatment plant is difficult to determine. In plants in which the gas produced in the plant is

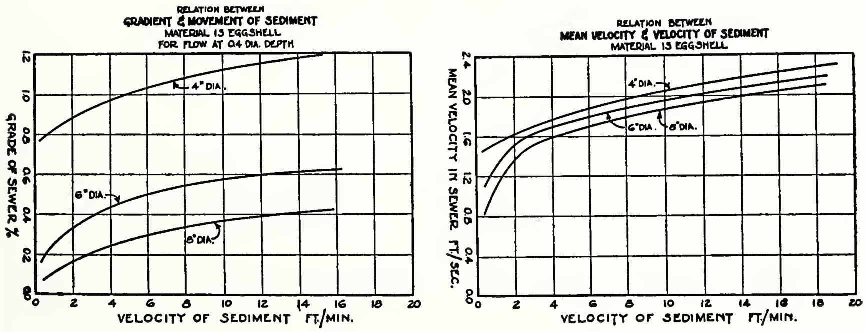


Fig. 98. The relationship of sewer grades, mean velocity of sewage, and sediment velocity of garbage was studied at the University of Texas in the late 1940's. That and other studies showed that the slopes of sanitary sewers then in use could satisfactorily transport the solids produced by domestic garbage grinders. (Reprinted with permission of The American City.)

used as fuel, savings in operating costs reportedly have been realized by processing ground garbage at the sewage treatment plant. The costs of sewage treatment for a home garbage grinder is usually about 50 cents to $1.50 per capita per year, depending upon the type of treatment plant and economic factors.

Municipal Collection System. The effect of garbage grinders on the municipal collection system may be great or almost negligible, beneficial or detrimental, depending on local conditions.

Cities that sell garbage for hog feeding notice a marked decrease in the amount of garbage collected as more and more people install grinders. Cities that operated self-supporting garbage collection and disposal systems before grinders were widespread may find that it is necessary to make a collection charge to those households that do not have grinders.

If a city has many old dwellings and little room for new construction, it is unlikely that home grinders will be installed in sufficient numbers to materially affect collection practices, since under such conditions, grinder installations are usually spotty. Installation of home grinders will cause no appreciable change in cities that have a one pick-up collection system, either, particularly if residents put all refuse out at the curb. The total weight of the refuse collected may drop as much as 20 per cent but the volume will be practically the same. The elimination of household garbage from refuse disposed of in a sanitary landfill or incinerator reduces collection and disposal costs relatively little.

In cities that use separate garbage and rubbish collections, and especially those in which the garbage is taken from yards in tubs, a considerable change in the collection system will be noticed if many home grinders are installed. Houses equipped with grinders can be omitted from garbage collection routes, speeding up service to other homes and reducing collection costs. If all the houses in an area have grinders, garbage collection can be discontinued there entirely. But surveys of all garbage collection routes must be made frequently if savings to the city are to keep pace with grinder installations.

Effect on Home Disposal Practices

The installation of a home garbage grinder has a number of effects on home refuse handling practices. The conventional covered garbage can usually is done away with because the garbage that is not put in the grinder is too small to require a large container; in most cases that garbage can be stored with the rubbish.

But home garbage grinders are not used for large bones and peach pits because the noise is more than most people will tolerate. Some food wastes, such as gristle and fish heads, which are rubbery, bounce around inside the grinder and require a long time to grind. Fibrous materials such as corn husks can stall the grinder unless they are fed into the grinder correctly. Seafood wastes, such as clam shells, can plug the drains and sewers.

Furthermore, not all food wastes that can be ground reach the grinder for one reason or another. During warm weather many people eat outdoors and dispose of food wastes on paper plates in a nearby rubbish container. In cities in which it is permissible to store rubbish in open containers, the practice of dumping ungrindable garbage into them can be a nuisance and a health hazard, since food wastes attract insects and rodents and cause unpleasant odors.

In any event, the installation of a home garbage grinder does not completely eliminate the garbage storage problem, and good housekeeping requires other means of disposal for some refuse, although on a smaller scale.

Costs

The costs of buying, installing, operating, and maintaining a home grinder vary according to the costs of the grinder, freight, labor, and building code requirements.

Grinders are easily and economically installed when a house is under construction because plumbing pipes, electrical circuits, and the sink itself are designed for a grinder.

The cost of installation in a house under construction is sometimes as little as $75, but the same installation in a house already built may cost $125 to $200 or more.

The problems and costs of installing grinders in old houses vary between houses. Those five to ten years old usually have a sink designed for a grinder; most have adequate plumbing so that changes are few; and many have ample electric circuits. But in some old sections of a city, the cost of installing a grinder is almost prohibitive. Some of the houses do not have adequate sewer lines to city mains; and in some the sinks and plumbing are so old and in such poor condition that it is necessary to install all new plumbing.

The practice of using basements for recreation rooms or laundries sometimes makes it difficult to install a grinder after a house is built. Installation usually requires that a portion of the basement ceiling be removed and sometimes a part of a wall or walls, which also requires redecoration. The cost of the grinder itself may be insignificant compared with installation costs.

A grinder can be installed in the laundry room of an old house at a fraction of the cost of kitchen installation. However, the main appeal—that of disposing of garbage at the point of origin—is lost.

A home grinder has a useful life of from 10 to 20 years, although with good care and maintenance it can last longer. Some servicing is required over the years because water seals wear out, electrical switches fail, rubber gaskets deteriorate, and motors fail.

Average annual costs to a householder for a $150 garbage grinder with a 20-year life expectancy installed when the house is built and if the costs are included in the mortgage are about $10.30 for purchase and installation at 5 per cent interest; $5 for repairs; $1 for water and electricity; and

75 cents for sewage treatment, for a total of about $17 a year. Costs for the same installation in an old house are probably about 50 per cent more, bringing annual costs to about $22.

Since local conditions affect costs, the figures given above are only general; they are not costs for any particular city or kind of grinder. In many cities the minimum charge for a service call is $5 regardless of how minor the repair is. In any event, the cost to the householder of a home grinder is usually greater than that of efficient collection and disposal systems.

Municipal Regulation

Experience shows that the installation of home garbage grinders should be regulated through local building codes or other ordinances. Since problems vary from one city to another, regulations also vary.

It may be necessary to prohibit by ordinance the installation of home grinders until adequate sewers are available or until the sewage treatment plant is enlarged.

If grinders are permitted and encouraged, their installation should be regulated for everyone's protection. Regulations give the city the power to control the types of grinders installed, assure compliance with the building code, assure the most favorable grind for the sewer system and treatment plant, and the right to inspect the installations. Cities that allow installation of grinders without permits have no way of knowing about them and inspecting plumbing changes and additional wiring. The slight increase in cost to the householder for a permit is justified.

One of the most controversial requirements for home grinders is the flow control switch that assures an adequate flow of water every time a grinder is used. If it could be installed without additional cost, it would probably be required by most cities to protect the householder, but in most cases it is not.

Many cities require that to be approved a home grinder must grind the garbage to a certain particle size for given amounts of garbage. The size of the particle is important in how the ground garbage gets through a sewer system and to the sewage treatment plant, but testing for particle size is difficult because of grease and other refuse in the garbage. No uniform standards for grinding had been established by early 1961, but a manufacturer of household grinders had drawn up these standards:

> The food waste shredder shall discharge shredded wastes at a reasonably uniform rate, in a fluid form, which shall flow readily through an approved trap, drain line, or soil line in a manner which will prevent clogging or stoppage of drain line. The food waste shredder shall shred food waste to a uniform size to meet the following requirements: 100 per cent shall pass a ½-inch screen, at least 90 per cent shall pass a ¼-inch screen, not over 5 per cent shall pass a No. 40 sieve. Screens shall be the U. S. Standard and weight shall be taken on a dry basis.

Some ordinances adopted for the purpose of encouraging or forcing installation of home grinders are both unrealistic and impractical. Premature abandonment of a garbage collection system even when householders are required to dispose of garbage in a manner approved by local health authorities can cause serious sanitation problems. In a large city such a requirement can create intolerable conditions. However, as already pointed out, the requirement that garbage grinders be installed in all new houses has met with success in some cities. Installation in some old houses can also be expected, but requiring installation in all old houses is considered impractical.

Public Acceptance

Garbage collection and disposal are not ordinarily subjects of general interest. They are necessary parts of housekeeping but of little public interest unless something is wrong with the systems. However, a well planned and conducted campaign to encourage installation of food waste grinders may make a substantial impact on a city. This has been demonstrated in Detroit; in Jasper, Indiana; and Shorewood Hills, Wisconsin.

A well conducted campaign can also speed up installations in old houses in small cities. The same efforts are much less effective in large cities, however, because a smaller proportion of the residents are home owners. Grinders are a fairly expensive convenience and the installation of them, therefore, is directly related to family finances, as well as the effectiveness of the campaign, whether it is sponsored by equipment manufacturers or by local government.

Grinders in Commercial Establishments and Institutions

Grinders are proving an excellent solution to the food waste disposal problems where large quantities of garbage are produced. Speed of operation, compactness, low operating costs, and freedom from nuisance assures that more and more will be installed in hotels, restaurants, food markets, hospitals, and other institutions and businesses. Relatively small grinders with 1½, 3, or 5 horsepower motors are commonly used.

The storage of food wastes in such establishments has always been a problem, especially from the sanitation standpoint. Garbage is produced in large quantities and in a relatively short time. Storage facilities are often inadequate and frequently are in the same area in which food is prepared. Problems with insects and rodents develop quickly unless sanitary measures are employed at all times. Usually daily garbage collections are required to eliminate odors. But the installation of a garbage grinder has substantially eliminated such problems for many businesses and institutions.

The grinder can be installed in a restaurant so that it serves both the food preparation area and the dish washing area. Garbage is ground as fast as it is produced. As with home grinders, however, oyster shells, clam shells, and large bones cannot be ground and must be stored and disposed of by other means. But they are only a small part of the wastes produced (except in sea food restaurants) so that for all practical

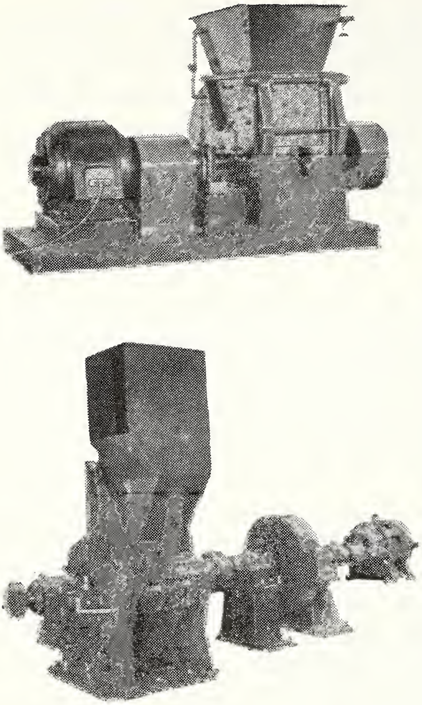


Fig. 99. There are two basic types of commercial grinders: the swing hammer mill type with rotating hammers that tear up the refuse and beat it to a pulp against a side plate (top), and those that use rotating knives, or shredders, which operate on the same principle as home grinders (bottom).

purposes, garbage storage is eliminated, which raises sanitation standards considerably in food preparation areas. Hotels have also found that use of grinders reduces the amount of silverware lost.

Centrally located grinders in large supermarkets are quite satisfactory. Supermarkets must dispose of large quantities of produce and produce wastes daily, and storage space is almost always limited because as much space as possible is used for the sales area.

Grinders have also been used effectively in food processing plants. It is relatively easy to install a grinder so that it is a part of the production cycle in such plants. Usually a conveyer belt carries all waste products to the grinder and the grinding and flushing process is automatic. Such a system requires a minimum of labor. Both hammer mill and shredder type grinders are used in processing plants, and they are usually larger than those used in most other businesses.

Produce terminals have large quantities of food wastes because most produce is perishable. It is sometimes necessary to dispose of an entire shipment of fruits or vegetables that arrives in poor condition—100 or more tons of only one product. It is not feasible to store such large quantities of spoiled produce; instead it is necessary to get it to a disposal point as quickly as possible.

A grinder centrally located on the premises of a produce terminal reduces hauling distances to a minimum. Fruits and vegetables are easily ground so that a relatively small grinder can dispose of large quantities of them in a short time. The grinder is usually equipped with a hopper and a conveyer system so that large truck loads of produce can be dumped without overloading the grinder. It operates continuously, controlled by the conveyer, without constant attention.

Because only a relatively small space is required for a grinder, several are sometimes installed in a large terminal; different sizes and types are used for different needs.

Types and Sizes

Commercial and institutional grinders are of two general types. One uses rotating knives, or shredders, and operates on the same principle as a home grinder. The food particles are ground between the rotating shredder plate and a stationary wear ring; water is used to flush the ground garbage into the sewer. The fineness of grind is controlled by the amount of space between the rotating and stationary sections. Grinders of this type may have vertical shafts like those in household grinders or they may have horizontal shafts. They are usually manufactured in small sizes, with motors up to 5 horsepower.

The other common type of grinder has rotating hammers that tear up the garbage and beat it to a pulp against a side plate; the garbage is flushed through a screen to the sewer. Hammer mill grinders can be built in small sizes but they are usually large, using motors of from 5 to 150 horsepower or more.

Effect on Municipal Services

Water Supply. It is difficult to generalize on the quantity of water required to operate commercial grinders. Some grinders require more water than others and the type of garbage ground affects the amount used. Furthermore, the size of the sewer into which the grinder discharges affects the amount of water needed. If the normal flow in the sewer is small, considerably more water must be used in the grinder to assure proper flushing and to prevent heavy solids from settling in the sewer pipes.

The amount of water used varies from about 5 gallons per minute for a small unit using a 1½ horsepower motor to about 20 gallons per minute for a unit with a 10 horsepower motor. About 1 gallon of water is required for each 1 to 2 pounds of ground garbage. Commercial grinders are usually operated only a small part of the day so that the amount of water needed daily is comparatively little.

Many cities charge for sewage treatment on the basis of the amount of water used. Commercial grinders put a high concentration of suspended solids into sewers and treatment plants without using an appreciable quantity of water. If the charge for sewage treatment is based on the amount of water used, it is possible for a produce terminal or food processing plant to install a grinder and get disposal service for only a fraction of its actual cost.

Sewers. Commercial grinders should not be installed in areas in which sewers are inadequate or faulty. A restaurant near a residential area sometimes has this problem. The lateral sewer may have insufficient flow or pitch to permit garbage from the restaurant grinder to flow to the main sewer. If a sewer stoppage results, not only the restaurant but often residents of the area are inconvenienced.

Sewage Treatment Plant. Ground garbage from commercial grinders does not present any unusual problems at sewage treatment plants. Restaurants, hospitals, food processing plants, and produce terminals put the same types of garbage through the grinder that householders do. The particle sizes may be larger than those from home grinders but they are usually small enough for efficient treatment. Commercial grinders differ from home grinders in that they put large amounts of suspended solids into the sewer system over an extended period of time. This is usually not noticeable at the treatment plant because of the dilution and leveling out processes as the ground garbage travels through the sewers. However, a produce terminal may contribute such large quantities of ground garbage that the treatment plant becomes overloaded. This problem can be solved, however, by regulating the time and the extent the grinder is used.

Municipal Collection System. Most municipal refuse collection systems are unaffected by installation of commercial grinders because commercial establishments are usually serviced by private collectors. Hog feeders often collect garbage from restaurants and hospitals even in those cities that provide collection services for businesses and institutions.

In many communities, however, the practice is to permit private collectors to dispose of refuse at municipal incinerators or sanitary landfills, either free or for a fee. The installation of commercial grinders reduces the need for such disposal services.

Limitations

Some garbage, such as oyster shells, large bones, and banana stalks, mentioned before, should not be ground. Neither can chicken feathers, hog bristles, and wool be ground successfully; if they are ground, they plug the unit. Thus a poultry processing plant, for instance, can use a grinder for only part of the waste produced; a collection service is needed for the remainder.

Costs

The cost of a 1½ horsepower commercial grinder is about $600 and a 5 horsepower grinder costs about $1,600. The expected life is from 10 to 20 years. Maintenance costs are relatively low because the grinders have only a few parts that wear.

The grinder itself is usually only a small part of the costs, because additional facilities such as metal chutes, sorting tables, storage hoppers, and conveyers are often needed.

Electric power used for a commercial grinder is relatively insignificant because the grinder is used only intermittently. Assuming an average charge of 2 cents a kilowatt hour, a grinder equipped with a 1½ horse-

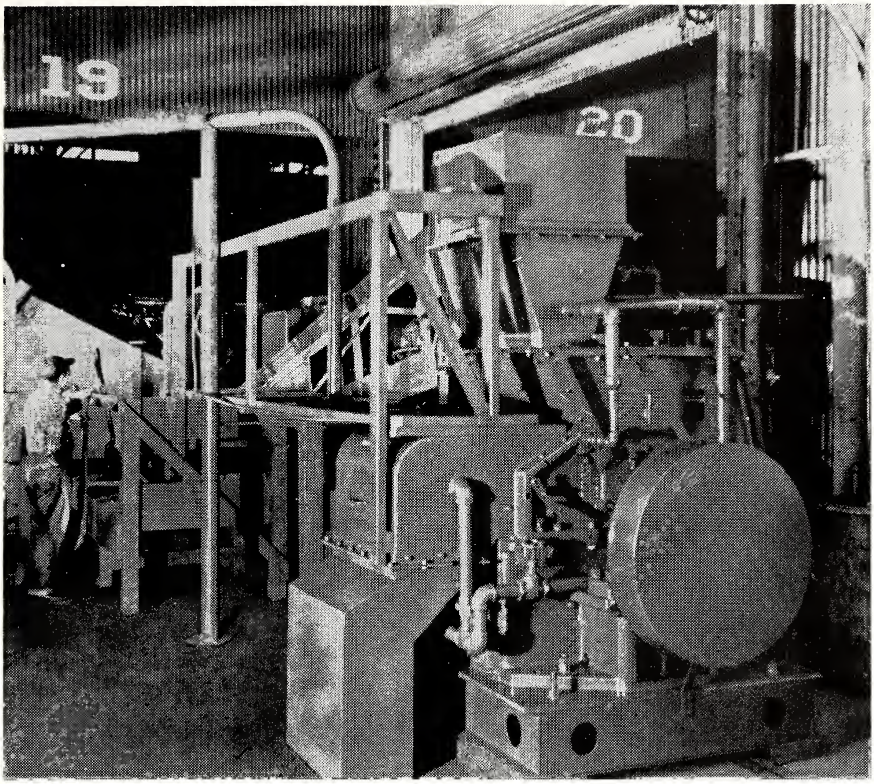


Fig. 100. Spoiled fruits and vegetables are conveniently disposed of in this grinder, installed by the United Fruit Company at its ship terminal in New Orleans.

power motor uses 3 cents worth of electricity an hour; it would cost 10 cents an hour for power for a 5 horsepower grinder. In restaurants and other places where food is served, the total time a grinder is in operation is probably considerably less than one hour a day.

Municipal Regulation

Ordinances pertaining to commercial grinders are of two types: (1) those dealing with approval of grinders, sizes of water lines, plumbing, and installation procedures; (2) those dealing with the broad field of refuse disposal. The second type either permits or prohibits the installation of commercial grinders because of their effect on the sewage disposal system.

A national model code for commercial grinders has not been developed; each city must work out its own standards for fineness of grind, standard refuse test mixture, and water. An acceptable model performance code would help eliminate confusion and help municipalities set up regulations.

Ordinances encouraging or requiring the installation of central grinders are usually only applicable to new buildings or to remodeled buildings in which production of food wastes is expected to increase. Some cities have explored the possibility of requiring installation of grinders in all commercial buildings where food wastes are produced; all have determined that such a requirement is not feasible.

Most ordinances that have to do with grinders but do not prohibit them are concerned with all kinds of on-site disposal; they are usually written to cover both grinders and incinerators.

Installation. Permits should be required for the installation of commercial grinders because records of permits are the most important single means of locating the sources of ground garbage in the sewer system. Many kinds of garbage that should not be ground may get into sewers if permits—and thus inspections—are not required. Furthermore, a permit requirement makes it possible to prohibit connections to sewers that are known to be inadequate. One city requires the business or institution installing a grinder to be responsible for damage to sewers.

The department responsible for issuing permits and inspecting installations should pay particular attention to the quantity of water supplied to the grinder. The amount is usually controlled by specifying the minimum size water pipe that can be used for a grinder and requiring an electrically operated water valve. A grinder so installed cannot be operated unless the right amount of water is flowing.

If limits on particle size are included in the ordinance, the responsibility for testing the installation rests on the department issuing the permit. The tests are performed after the installation has been inspected and approved as far as other ordinance requirements are concerned. Testing large commercial grinders for fineness of grind is difficult because a large quantity of test refuse is required and it is difficult to get a representative sample.

Use

Grinders are being installed in most new commercial buildings in which food disposal facilities are needed unless grinders are prohibited by law. A commercial grinder is easy to maintain, gives long service, requires little space, and is a comparatively inexpensive method of disposing of garbage.

Many grinders have been installed in older buildings because they are convenient, and many more such installations will be made. The commercial grinder has solved the problems of garbage disposal in hospitals and other institutions so efficiently that it is considered almost a necessity.

Grinders are usually installed in large, successful restaurants for convenience and to improve sanitation. The small neighborhood restaurant that constantly changes ownership is a different problem, however. The business may not be profitable enough to warrant installation of a grinder.

The benefits of grinding stations at produce terminals and food processing plants have been quickly recognized, especially in cities in which the only disposal charge is included as a small part of the water bill.

Probably the single most important factor that has prevented 100 per cent installation in areas where grinders are permitted is that they cannot grind all food wastes.

MUNICIPAL GRINDER STATIONS

Centrally located municipal garbage grinder stations are in use in a number of cities. If garbage is collected separately from other refuse, grinding is a convenient way of disposing of it, particularly wet garbage not suitable for incineration or hog feeding.

Types and Sizes

The garbage from a city of 80,000 people can be disposed of daily at a station that grinds 5 tons an hour or even less. An installation of this size requires little equipment and facilities in addition to the grinders. The garbage can be dumped on a concrete floor, sorted for objects that cannot be ground, and the rest manually pushed into the grinder. Where only one or two loads of garbage are collected each day, it may be much more economical to use part-time labor than to mechanize operations.

Grinder stations in large cities receive large quantities of garbage in relatively short periods of time, which has led to the development of grinders that can process 30 to 50 tons of garbage an hour. Such installations are highly mechanized.

How well garbage is prepared and separated from other refuse by the householder largely determines the type of plant that should be built.

Garbage with a high moisture content (swill) that is free of cans, glass, and other ungrindable objects is the most suitable for grinding. The equipment usually needed consists of a receiving hopper, a conveyer, and a grinder. Some sorting is done on the conveyer line to remove an occasional can or bottle. The initial cost for such a plant is low, maintenance costs are low, a minimum of labor is required, and the plant has a high disposal rate per hour. Plants of this type have been built in cities in which the practice of feeding garbage to hogs has been abandoned or to dispose of garbage that is surplus from a hog feeding program. Grinders of this type are sometimes installed in an incinerator plant to handle spoiled produce or swill, which is easily ground but difficult to incinerate.

Wrapped garbage requires a much more complicated grinder plant. Packages of wrapped garbage usually contain ungrindable materials that must be exposed before they can be removed.

The plant designed to grind wrapped garbage should have two sections. The first section includes a receiving hopper where trucks dump their loads, a conveyer that carries the garbage at a uniform speed to the primary grinder, and the primary grinder that shreds the packages and exposes the contents. This grind is extremely coarse, and only a small amount of water is used because the garbage must be sorted before the final grind. The primary grinder discharges its material to the second section. The second section consists of a conveyer that carries the refuse to a picking belt; the picking belt, which discharges the sorted

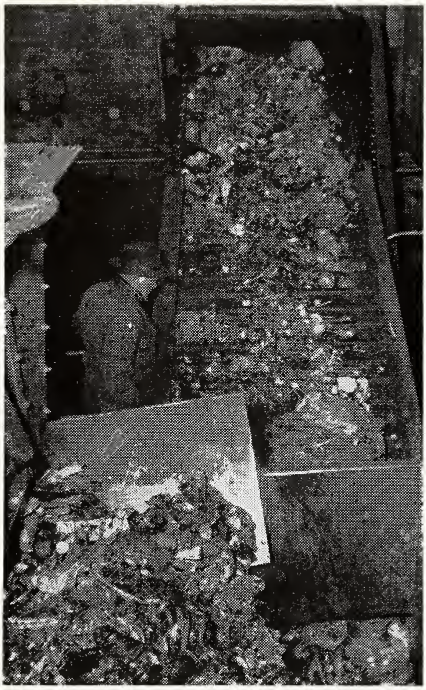


Fig. 101. An attendant inspects garbage being carried on a picking belt from a storage hopper to a grinder at the Washington, D. C., refuse transfer station. Objects often found in garbage that are harmful to grinders, such as heavy metals, should not be put into grinders.

refuse to the final grinder; and the final grinder, where garbage is reduced to the correct size particles and flushed into the sewer. On the picking belt, ferrous metals are usually removed by a magnetic pulley and nonferrous metals, concrete, and other objects are removed manually.

The large grinders used in municipal plants are usually of the hammer mill type. There is considerable wear on the hammers because all municipally collected garbage contains some ungrindable objects, especially if wrapped garbage is processed.

Location

Municipal grinder plants may be located near load centers to reduce hauling costs or they may be at the sewage treatment plant where the ground garbage can be deposited directly in the digesters. This requires less investment in treatment facilities than if the ground garbage must be processed through the entire treatment plant. Each city must make studies to determine what location is most economical for it, however.

In large cities, grinder stations are usually located along main sewer interceptors. Hauling costs become important as the number of trucks and driving distances become greater. Several grinder plants can be so located that hauling distances to each are minimum. Furthermore, by putting the ground garbage into the sewer system at several locations, the load at the sewage treatment plant is leveled out over a period of time and problems of treatment are not as great.

Small cities usually find the most economical location for a grinder is at the treatment plant. If only a small amount of garbage is ground daily it is often possible to use the workers at the treatment plant to grind the garbage, which results in considerable savings. Another advantage is that the people responsible for grinding also learn the limitations of the treatment facilities and are able to work out the most desirable techniques for both grinding and treatment.

Effect on Municipal Services

Water Supply. The water requirements of a municipal grinder station vary considerably with type of station, location, and the kind of refuse processed. Grinders located in sewage treatment plants can use the effluent from the secondary treatment for all operations, and the amount of water needed is reduced considerably when the garbage is pumped directly into the digester. Grinder stations on main sewer interceptors that have a high normal flow rate can use sewage to supply a good share of the flushing water. When city water is used for the grinding process, it usually requires about 1 gallon for each pound of garbage ground. The quantity varies considerably, however, if flushing problems are severe and higher flow velocities are required.

Electric Power. The cost of the power consumed by a municipal grinder station is relatively low. If city water is used, most of the power is for the grinders, with a small portion for the conveyers. If power is charged for at the rate of 2 cents per kilowatt hour, power costs for grinder stations vary between 10 cents per ton of garbage ground for a simple station to 30 cents for one using primary and secondary grinders and an elaborate conveyer system.

Sewage Treatment Plant. The discharge of ground garbage from a central grinder station into the sewer system presents additional problems at the sewage treatment plant. The problems are similar to those with home grinders. There is a marked increase in the amount of suspended solids received at the treatment plant when the grinder station is in operation; there is a noticeable increase in grit unless the grinder station is equipped with a grit chamber to wash the slurry before discharging it into the sewer; there is an increased organic load on the secondary treatment process. If a plant is operating at or near capacity before a grinder station is built, the treatment plant must be enlarged before the station can be operated.

If the grinder station is built at the sewage treatment plant, the slurry from the grinder can be pumped directly to the digesters, thereby eliminating the need for increased plant facilities other than on the digesters and for sludge disposal.

Some cities still dump sewage into streams of water without treating the sewage. Those that do can build a grinder at any convenient location without giving thought to fineness of grind, grit, grease, and increased suspended solids. However, the practice of dumping untreated sewage in water is rapidly being eliminated, and it is doubtful if any new plants will be constructed for direct discharge into streams.

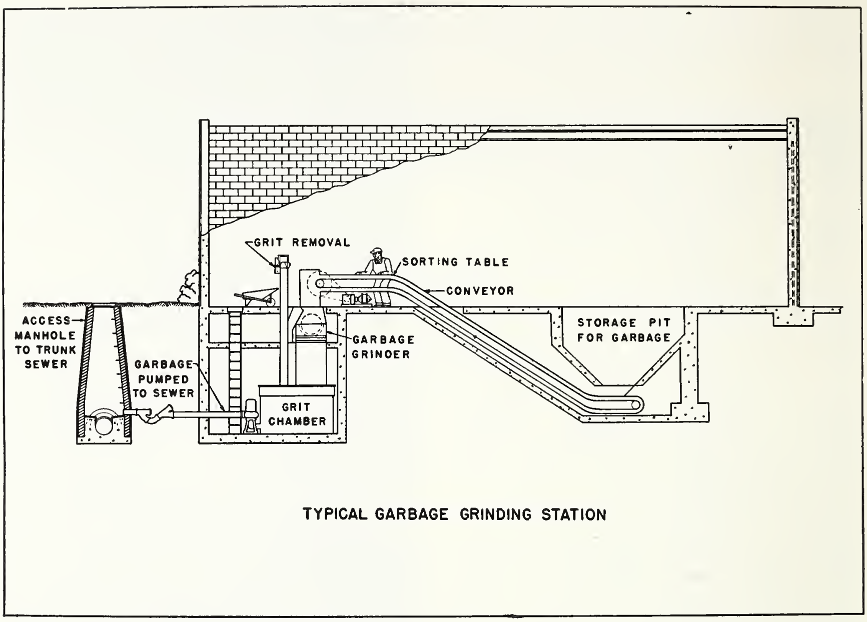

GRIT REMOVAL
SORTING TABLE
CONVEYOR
ACCESS MANHOLE TO TRUNK SEWER
STORAGE PIT FOR GARBAGE
GARBAGE GRINDER
GARBAGE PUMPED TO SEWER
GRIT CHAMBER
TYPICAL GARBAGE GRINDING STATION

Fig. 102. A cross section of the layout for a central garbage grinding station.

Safety

Municipal grinder stations are relatively safe. Experience shows that when reasonable care is exercised in removing materials such as heavy metals that are unsuitable for grinding, the possibility of injury from flying objects rejected from the grinder is remote. The concrete walkways are usually wet and slippery, so employees must be careful when they walk around the equipment; guard rails should be provided.

Odor Control

A grinder station can cause considerable odor unless the air is deodorized before it leaves the plant. To do this, equipment must be housed in a building maintained under negative pressure while garbage is being ground. This prevents air from escaping together with garbage odors except through the air purification equipment located on the exhaust side of the ventilation system. The discharge of the purified air through a stack extending some distance above surrounding buildings also helps eliminate odors.

Costs

There are many factors and variables involved in the costs of a municipal grinder station.

If a small, five-ton-per-hour grinder is installed in a sewage treatment plant, the total cost of the installation may be less than $10,000, and the equipment should last for at least 15 years. Assuming that 10 tons of garbage are processed daily, the costs will be about 25 cents a ton.

Costs for a large municipal grinder station located on a main interceptor are at the other extreme. A 300-ton-per-day plant consisting of an enclosed dumping area, primary and secondary grinders, conveyers, standby equipment, air purification equipment, employees' facilities, and so on requires a sizeable capital investment. The building would probably cost in excess of $300,000 and could be expected to last at least 30 years. Equipment would cost about the same amount but it would be depreciated in 20 years. Costs for such a plant would be about 40 cents a ton of ground garbage. Operating and maintenance costs would vary between 50 cents and $1 a ton.

The type of sewage treatment plant and the degree of treatment influence costs. Cities in which garbage is ground at the treatment plant and pumped into the digester and in which the gas produced in the digester tanks is used as fuel in the operation of the plant have reported savings in treatment plant operating costs. Other cities have reported a cost of more than $3 a ton of garbage processed. In view of the conflicting reports, each city must study its own conditions and evaluate the cost of grinding in terms of known costs of operating collection and disposal systems and a sewage treatment plant. Garbage disposal is only

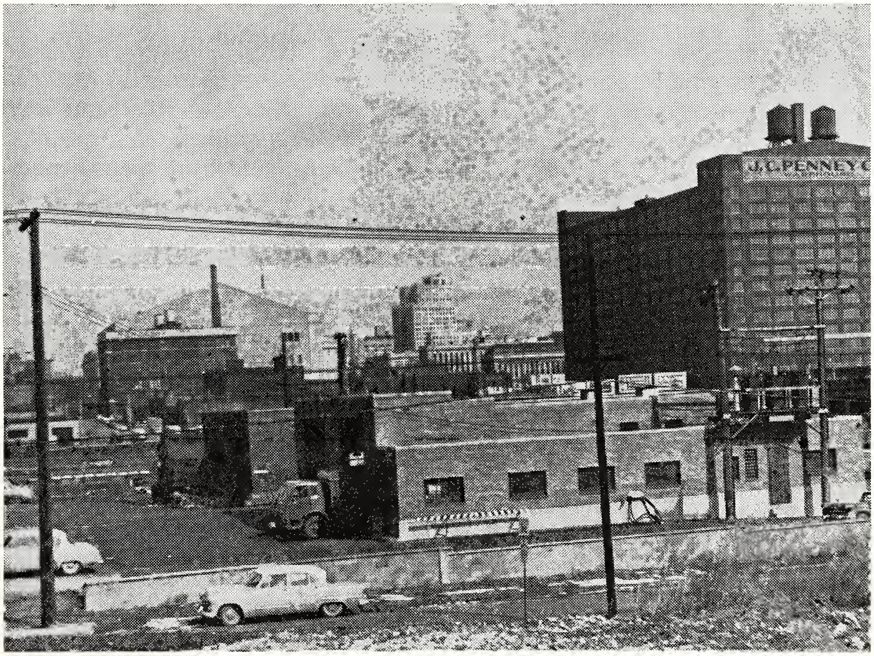


Fig. 103. This garbage grinding station in St. Louis, which looks much like a garage, has a near-downtown location.

one small part of refuse disposal. The best solution is the one that conforms to sanitation standards at the lowest cost.

Evaluating Grinding as a Disposal Method

If garbage is to be ground it should be collected separately from other refuse, so a city must have at least two collection systems. Plant construction is simplified and operation is more economical if only garbage that is free of hard-to-grind objects is ground. Sanitary landfills or other methods of refuse disposal are also necessary to dispose of ungrindable refuse.

If disposal sites are some distance from the city, the installation of a central grinder plant may reduce hauling distances so that garbage can be collected with fewer trucks and fewer man-hours. The savings may more than offset the cost of the grinder plant.

Large cities that use incineration as the primary means of refuse disposal also use grinders to advantage for some refuse. It is difficult to burn large loads of tomatoes and watermelons, for instance, from produce houses. A grinder makes it possible to dispose of such refuse quickly, easily, and economically.

It is doubtful if a large city can justify use of central grinder stations for all garbage disposal. The need for only one collection system with either incineration or landfill disposal offsets any possible savings of central grinding.

The Future of Food Waste Grinding

Any attempt to prognosticate the future of garbage grinders must be based to a large extent on experience during the past 10 years. The effects of grinders on sewers are well known; it is unlikely that grinders will ever be limited because of sewer problems except in special cases. Ground garbage behaves much like sewage solids in treatment plants, so no new and startling discoveries can be expected there that would greatly influence the acceptance of grinders.

It has been suggested that grinders could be developed to handle other solid wastes and thus increase their effectiveness and appeal to the householder, although such a grinder probably could not be installed in the kitchen sink because of the heavy-duty work it must do. By the early 1960's, however, there was little promise that a feasible and practical grinder of this type would soon be ready for marketing.

Built-Up Cities

Cities that are almost completely built up will not be affected to any great extent by the installation of grinders during the next 10 years. Most new houses in the middle and upper price brackets and some low-cost houses will be equipped with grinders. Experience indicates that approximately 75 per cent of the houses in the middle and upper price levels that were less than 10 years old in 1960 will have grinders by 1970; and 20 per cent of the houses from 10 to 30 years old in 1960 will have grinders installed in 10 years. Houses over 30 years old are a poor market—less than 5 per cent will add this improvement. In a city that is 80 per cent developed and in which about 10 per cent of the houses are equipped with grinders, it can be expected that in 10 years 40 per cent of all new houses will have grinders.

Many hospitals, restaurants, produce houses, and other businesses that produce large quantities of food wastes have already installed grinders, and most businesses that need grinders will include them in new buildings if they are permitted under local ordinances.

Cities that are growing little probably will not have a big enough increase in the number of grinders to change collection and disposal systems, but changes in sewage treatment facilities may have to be made.

Growing Cities

Most growing cities must plan for a large increase in the number of home garbage grinders. Unless a city prohibits them, it can anticipate that most new houses in the middle and upper price brackets will have grinders. All will have disposal units if installation is required by ordinance, of course.

A growing community can predict reasonably accurately the saturation limits of acceptance. Where installation of grinders is controlled by ordinance, estimates of future use can be made reliably. Promotion campaigns with or without ordinance assistance affect the number installed.

About 50 per cent of the older houses in growing cities probably will have grinders. Houses built for low income groups, where the selling price is important, probably will not have grinders unless they are required.

Suburbs

The number of home grinders that can be expected in suburbs is difficult to assess. Most suburban houses are on large lots, so that storage of refuse is not as difficult as it is in a city. Many suburbanites hire private refuse collectors, usually for both garbage and rubbish, who charge a monthly fee. In some areas in which air pollution problems are not critical both garbage and rubbish are burned outdoors. Furthermore, septic tanks are used for sewage disposal in many suburban houses and although grinders can be used with septic tanks if both the tank and the tile field are large enough, a grinder may increase construction costs of the septic tank system by as much as 50 per cent.

On the other hand, most suburbanites probably can afford garbage grinders better than most city dwellers.

Summary

Grinders are neither a panacea nor a passing fad. They have been in use for more than 30 years. While many have been installed in the past

10 years and they have grown in popularity, they cannot be expected to compete with refrigerators and washing machines in acceptance.

The acceptance or rejection of appliances normally concerns only the manufacturers and distributors. Garbage grinders are an exception, since acceptance or rejection can be important to a city. If a city wants 100 per cent use of grinders so that it can do away with garbage collection, refusal by 25 per cent of the home owners can nullify the program. On the other hand, a city that has inadequate sewers or sewage treatment plant cannot depend on home owners *not* to buy grinders; it must prohibit their installation.

All cities have a garbage grinder problem in one form or another, whether it is recognized or not. Sooner or later each city has to evaluate grinders in terms of city needs and conditions. Some cities under some conditions will have 100 per cent use of home grinders. But even those cities will not grind all the garbage produced; the amount probably will be less than 10 per cent of the total refuse normally collected and disposed of by the municipality.

Home grinders are usually considered a luxury, but as living standards continue to rise, more and more people will reach an income level at which they become a household necessity.

8 FEEDING FOOD WASTES TO SWINE

In colonial times the problem of garbage disposal in large cities was "solved" by turning pigs loose in the streets to serve as scavengers. In view of today's sanitary practices, such a system seems remote, indeed. However, in small communities a pig or two is still frequently the garbage disposal plant for a family. Traditionally, farmers have kept a few hogs that were "slopped" after mealtime with the leftovers from the table, trimmings from the preparation of food, and other edibles. Into this melange were sometimes thrown a few handfuls of grain.

As cities grew, owners of small farms in outlying areas found it profitable to collect all or part of a city's garbage as food for their livestock. When cities became so large that hundreds and then thousands of families were living in close proximity, the garbage disposal problem became acute, and regular garbage collection and disposal became a matter of public health.

It was about this time that city governments began to contract with private individuals to collect all of the garbage in the city. The garbage often was used for hog feeding by the contractor himself or resold to the contractor's customers. With this arrangement, the city retained control of the operation and could demand that pickups be made at regular intervals and that all parts of the city be served by the collection trucks. Other cities found it more convenient to collect and dispose of garbage with their own crews and equipment.

Despite the fact that there is a statistical correlation between the practice of feeding raw garbage to hogs and the relatively high incidence of trichinae infection in humans in the United States, the practice was not changed for many years. The rapid spread of a virus disease of swine between 1953 and 1955—vesicular exanthema—prompted the states to enact legislation prohibiting feeding of raw garbage to swine. Agricultural authorities had said that the disease was spread largely because raw garbage was fed to swine. The United States Bureau of Animal Industry reported that more than 400,000 swine had to be slaughtered because of the outbreak.

When laws required that garbage be disinfected before it could be fed to swine, the problem of how to do it arose. Cookers of every type and size were soon developed, but a great deal of experimentation was necessary to find the best method of both thoroughly and economically cooking the garbage. Many questioned whether feeding garbage to swine could be continued economically.

However, owners of both large and small farms, recognizing the value of garbage as feed, have continued arrangements to get garbage from cities. It is estimated that more than 10,000 tons of food wastes, or about 25 per cent of the total quantity of garbage produced, are used for this purpose daily in the United States. Indications are that this method of disposal will be used for some time, and it is, therefore, of interest to public works officials responsible for refuse disposal.

Few if any municipalities now directly operate piggeries. A farm operated by the municipal government of Kansas City, Missouri, for many years, on which labor available from a correctional institution was used, was closed in the late 1950's.

Problems and Nuisances

Feeding garbage to swine causes problems—some for humans and some for the swine. Some of the problems result from the operation of a farm on which swine are fed garbage, some result from the pork products put on the market.

Problems for Humans

Trichinosis in humans is a disease caused by a round worm contracted when people eat raw or insufficiently cooked meat that is infected with the worm. Pork is a common source. Swine become infected by eating raw pork scraps or infected rats but usually no symptoms are evident in the live animal and the trichinae may even escape microscopic examination of muscle tissue after death. In humans, however, trichinosis is characterized by the onset of symptoms of varying intensity, according to the amount of infected meat eaten and the abundance of trichina in it.

At one time between 6 per cent and 11 per cent of the pigs fed raw garbage were infected with trichinae. However, the incidence has declined since laws require that garbage be cooked. Studies by the United States Department of Agriculture show that the proportion of garbage-fed hogs in Massachusetts infected with trichinae dropped from 11.2 per cent in 1952 to 2.7 per cent in 1958.

Hog farming is an agricultural pursuit and has no place in a built-up area, and particularly not in a residential area. Odors cannot be eliminated from even the best operated and cleanest farm, and although odors are not a hazard to health, they are objectionable and a public nuisance.

Flies are attracted in large numbers wherever livestock is kept, and particularly where garbage is fed to swine. Feeding and watering areas, pens, sheds, and compost piles are potential fly breeding areas. Sanitation practices, use of insecticides, and disposal of manure and other wastes are necessary for control. But it is impossible to completely eliminate flies, and since they are a threat to health, they are not acceptable, particularly in heavily populated areas.

Wherever garbage is kept or fed to animals, rodent infestation is a possibility. Feeding areas and shelters of piggeries must be properly constructed and sanitary measures used that will prevent rodents from gathering and feeding.

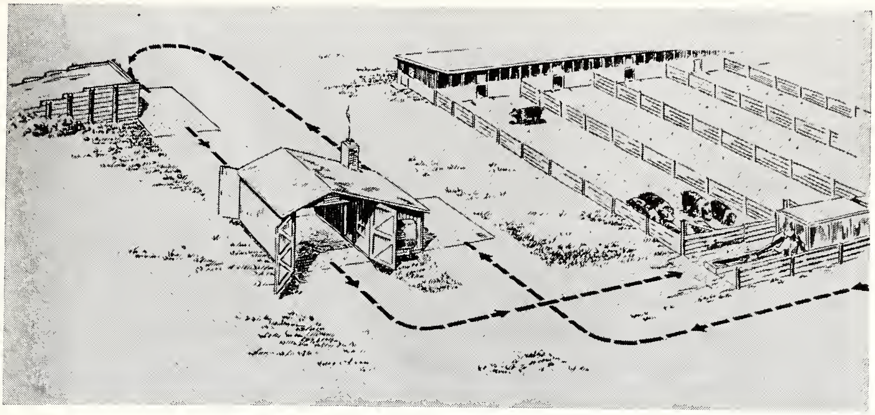
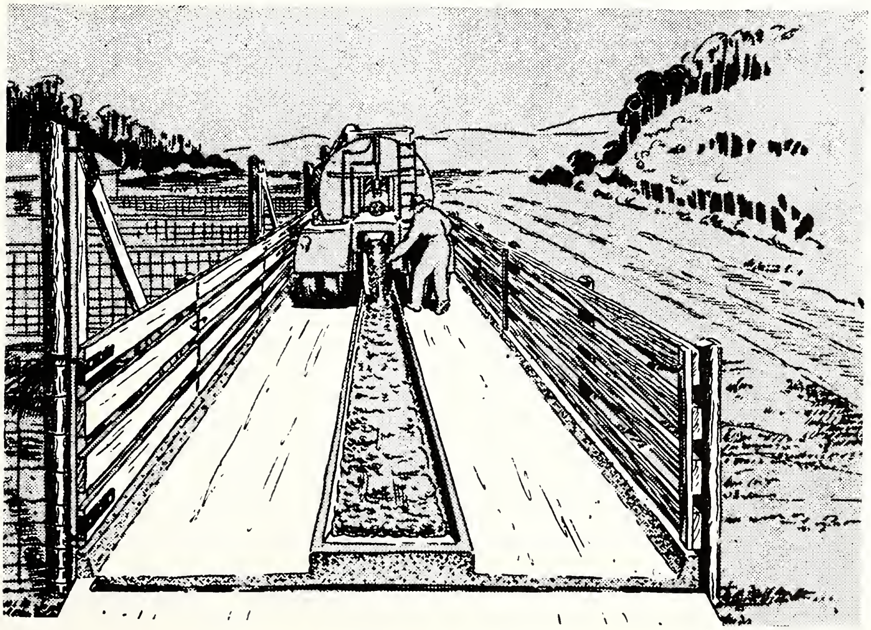


Fig. 104. Although municipalities do not operate farms on which hogs are fed garbage, the officials responsible for refuse disposal often find it a good method of garbage disposal and are concerned with the layout, operation, and cleanliness of such farms. This layout consists of a ramp for dumping garbage from collection truck into cooking truck, a cooking shed with a boiler where steam is turned into the load of garbage, and a drive-through alley 10 feet wide, with a feeding trough in the center, as shown below. This design was based on an allowance of 15 inches of trough space per hog to finishing weight.



Animal Problems

Swine that are fed food wastes are susceptible to the same diseases as those fed grain, and in addition they are susceptible to vesicular exanthema, hog cholera, and enteritis diseases, which may be spread by the consumption of infected raw pork scraps.

Vesicular exanthema, which is clinically indistinguishable from the dread hoof and mouth disease, occurs mainly in swine fed on raw garbage. It may also infect grain-fed pigs but it does not normally attack other domestic animals and it has never been known to attack humans. Obviously, cooking of garbage is essential to control.

Hog cholera causes an estimated $50 million a year loss to swine raisers in the United States. Vaccination against the disease is necessary in almost all sections of the country. Since the virus can be carried in raw garbage, swine so fed are continually exposed to infection. Probably the most important benefit to hog raisers from the laws requiring that garbage be cooked is the possibility of eventual eradication of hog cholera.

Swine fed on garbage often get one of the diseases in the enteritis group because they are more often exposed to bacterial infection than those fed on grain.

Pork from Garbage-Fed Swine

Pork quality is based on the type of fat found on the carcass of the pig—hard, medium, soft, or oily. Barley usually produces hard fat, corn the lower limit of the hard grade, and soybeans and peanuts produce soft or oily fats.

According to studies made by the University of California Agricultural Extension Service, most of the pork production of 92 pigs in three herds fed cooked garbage was hard. Of the 92 pigs, 73 produced pork graded hard; 13, medium hard; 3, medium soft; and 3, soft.

Ordinary garbage collected from residences in Los Angeles and cooked produces carcass fat of which approximately 75 per cent is hard, 20 per cent medium, and 5 per cent oily.

Abnormal odors or flavors do not occur any more frequently in pork from garbage-fed swine than in swine raised on grain or other feed.

The type and grade of meat produced in garbage-fed swine are influenced by the same conditions and factors as those fed on grain. Breeding is of prime importance in producing a good meat hog with a high-grade carcass. Good husbandry and sanitary surroundings also play a part.

The feeding time required to reach an average market weight of 220 pounds is somewhat longer for a garbage-fed pig than a grain-fed pig. It takes about 10 months for a pig to reach market weight if it is fed on Los Angeles household garbage (seven to nine months for a three-month old feeder, depending on its initial weight). Six to eight months is average for grain-fed pigs. However, the cost for each pound of weight gained is the main factor in determining whether grain feeding or garbage feeding is more economical.

Local, State, and Federal Regulations

Local. Most local health agencies require that premises where animals are kept be sanitary and that odors, flies, and rats, which may be nuisances and a threat to the public health and welfare, be controlled.

Local zoning ordinances usually permit hog farms only in certain districts. Some local governments require that a license be obtained before a garbage feeding hog farm can be operated. Los Angeles County has had such a requirement since 1926. Plans for construction and maintenance of such a farm must be approved by the county livestock inspector before a building permit can be obtained. Weekly inspections are made by veterinarians of the county livestock department to check the health of the animals and to insure compliance with county and state regulations.

State. All states require that garbage fed to swine be cooked. In addition, many have minimum construction and sanitation requirements for piggeries.

Federal. The federal government prohibits movement across state lines of animals that have been fed raw garbage, as well as pork and pork products from such animals. It also prohibits movement across state lines of garbage that is to be fed raw to swine. In cooperation with the states, the United States Department of Agriculture and the Public Health Service of the United States Department of Health, Education, and Welfare encouraged legislation requiring that garbage be cooked; the recommendations of these departments are the basis of most state laws.

Characteristics of Garbage Used for Feed

Neither the quantity nor the quality of garbage remains stable long. Geography, the season of the year, frequency of pickups, and even the economy of the city affect the composition and quantity of garbage.

The United States Department of Agriculture, reporting on studies of the chemical composition of garbage in New Jersey and Virginia in 1956, said that in both states samples collected from restaurants, households, and institutions were judged to be nutritious. In New Jersey, samples were tested before and after cooking, which was found to have little effect on the nutritive value of the garbage. A vitamin analysis was also run on the samples and it was found that there was no significant change. However, keeping the garbage at high temperatures overnight caused a slight decrease in vitamin content. This decrease was not important unless the garbage contained insufficient vitamins before it was heated.

The amount of garbage required to feed an animal depends on the size of the animal and the type of garbage it is fed. Less garbage is required if it comes from a military installation than from households because there is more inedible material in household garbage.

There are three principal sources of garbage: residences, businesses and institutions (including restaurants), and markets. In some localities military installations also are a source of garbage.

Residential Garbage

Residential garbage ordinarily has the poorest value as hog feed. It invariably has in it significant amounts of inedible materials such as glass and razor blades. However, the quantity of garbage is steadily decreasing with modern packaging and refrigeration. More garbage is wrapped, too, which increases the paper content of the garbage.

Commercial and Institutional Garbage

Commercial and institutional garbage also contains inedible materials—paper, china, lamp bulbs, silver, napkins, cigarette and cigar butts. In fact, they are the rule rather than the exception. Restaurant garbage exceeds residential garbage in nutritional value as hog food, however, primarily because of the larger quantities of inedibles in residential garbage. Also, garbage is usually collected more frequently from commercial establishments and institutions and is in better condition than residential garbage, especially in summer.

Market Garbage

Garbage collected from markets is predominately fruits and vegetables. It is not unusual to receive entire carloads of squash, melon, and other foodstuffs that are unsaleable and thus become garbage. Trimmings alone from a large city market can make up several truck loads of garbage a day. However, garbage from markets is made up of foods that have almost the same nutritional values and so it must be mixed with other foods to make it suitable for hog-feeding.

Garbage from Military Installations

Military installations are usually a good source of food wastes for swine feeding. The garbage is from well balanced meals, and the inedible wastes, such as coffee grounds and egg shells, are separated from edible wastes better than in other sources of garbage.

Methods of Cooking Garbage

Cities have tried various methods of cooking or treating garbage before it is used as feed. One method is to dehydrate; another to remove the grease; but cooking is the most effective. Equipment is readily available and hog raisers are familiar with it.

Several methods of cooking garbage have been discontinued because they were unsuccessful. Pressure cooking is one. Dry garbage sticks to the sides of the cooker with the result that all the garbage scorches, making it unpalatable. Dry steaming in a jacketed kettle also has largely been discontinued.

Garbage is usually cooked by one of two methods—direct fire or wet steam injections.

The direct fire method is merely cooking it in a vat set in a walled-in firebox (Figure 105). About 90 per cent of the equipment used to treat garbage is of the direct fire type. It is popular because it costs less than

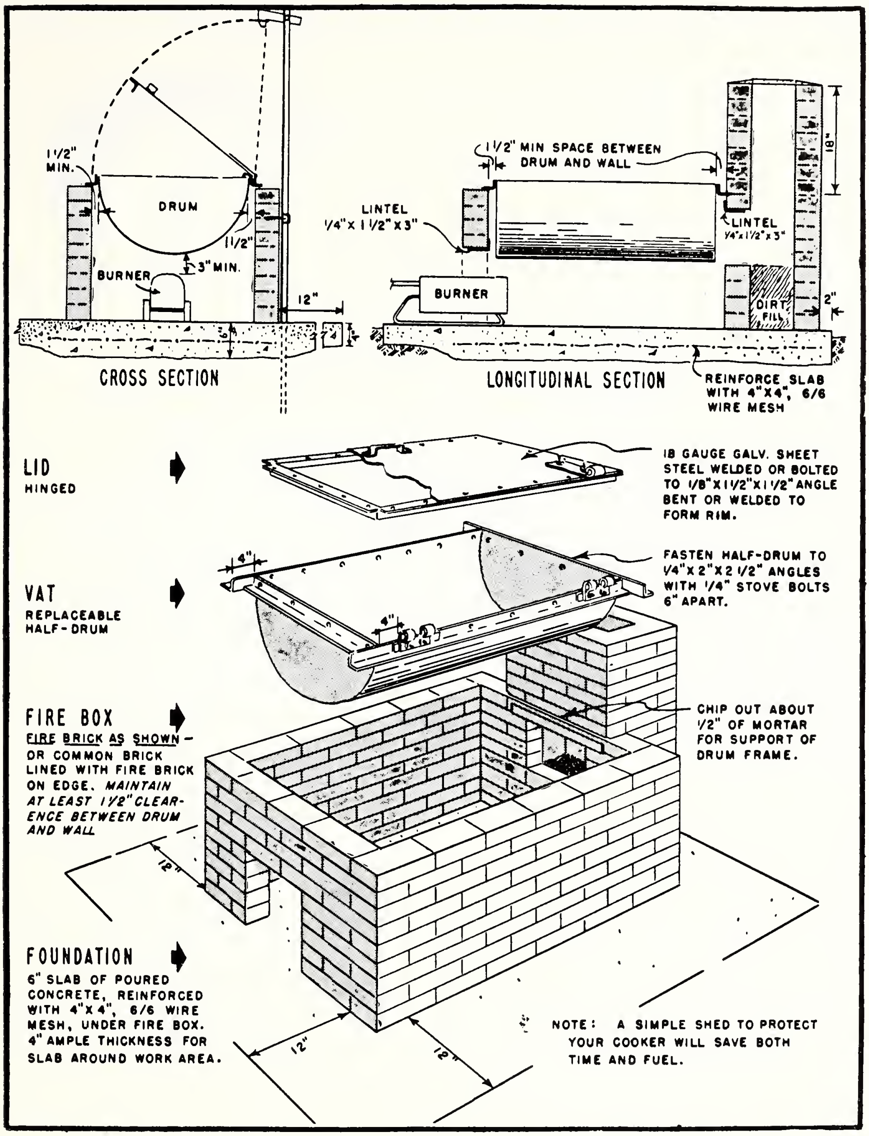

1 1/2" MIN.
DRUM
1 1/2"
3" MIN.
BURNER
12"
6"
4"
CROSS SECTION
1 1/2" MIN SPACE BETWEEN DRUM AND WALL
LINTEL 1/4" x 1 1/2" x 3"
LINTEL 1/4" x 1 1/2" x 3"
18"
BURNER
DIRT FILL
2"
LONGITUDINAL SECTION
REINFORCE SLAB WITH 4"X4", 6/6 WIRE MESH
LID
HINGED
18 GAUGE GALV. SHEET STEEL WELDED OR BOLTED TO 1/8"X1 1/2"X1 1/2" ANGLE BENT OR WELDED TO FORM RIM.
VAT
REPLACEABLE HALF-DRUM
4"
4"
FASTEN HALF-DRUM TO 1/4"X2"X2 1/2" ANGLES WITH 1/4" STOVE BOLTS 6" APART.
FIRE BOX
FIRE BRICK AS SHOWN — OR COMMON BRICK LINED WITH FIRE BRICK ON EDGE. MAINTAIN AT LEAST 1 1/2" CLEARENCE BETWEEN DRUM AND WALL
CHIP OUT ABOUT 1/2" OF MORTAR FOR SUPPORT OF DRUM FRAME.
12"
FOUNDATION
6" SLAB OF POURED CONCRETE, REINFORCED WITH 4"X4", 6/6 WIRE MESH, UNDER FIRE BOX. 4" AMPLE THICKNESS FOR SLAB AROUND WORK AREA.
12"
12"
NOTE: A SIMPLE SHED TO PROTECT YOUR COOKER WILL SAVE BOTH TIME AND FUEL.

Fig. 105. Garbage is often cooked by the "direct fire" method in an outdoor cooker.

$100, can be built by the hog feeder, and different types of fuels can be used. The trend now is to use liquid fuel or gas instead of wood or old tires. A great deal of improvement is necessary to make many of these cookers efficient, however.

The wet steam injection method is commonly used with large loads hauled from cities by private contractors. It consists of injecting steam

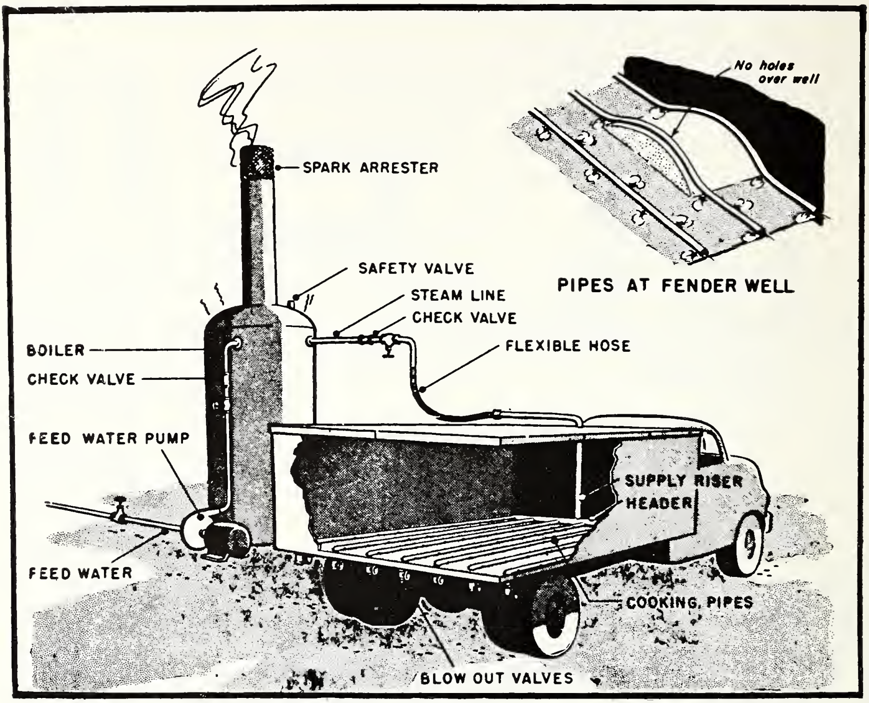

No holes over well
SPARK ARRESTER
SAFETY VALVE
STEAM LINE
PIPES AT FENDER WELL
CHECK VALVE
FLEXIBLE HOSE
BOILER
CHECK VALVE
FEED WATER PUMP
SUPPLY RISER
HEADER
FEED WATER
COOKING PIPES
BLOW OUT VALVES

Fig. 106. Garbage can be cooked by injecting steam into the especially equipped trucks that collect it.

into the load of garbage through perforated parallel pipes at the bottom of the body of the hauling vehicle (as in Figure 106). The steam comes from a boiler on a truck or from a vat. If the boiler supplies about 270,000 B.T.U. of steam for each ton of garbage treated, it takes 2½ hours to cook the garbage.

Much of the equipment used for this method of treating garbage could be improved by putting a tight lid on the vat and adding valves at the end of the injector pipes so sediment can be removed. Either high- or low-pressure boilers are suitable, although more water is added to the load when low-pressure boilers are used.

Heat treating in truck bodies is common because a cooking vat is not necessary. In addition, less labor is required because the raw garbage need not be taken from the truck and put in a vat. Concrete tanks are not suitable because the garbage that is in contact with the concrete does not cook thoroughly.

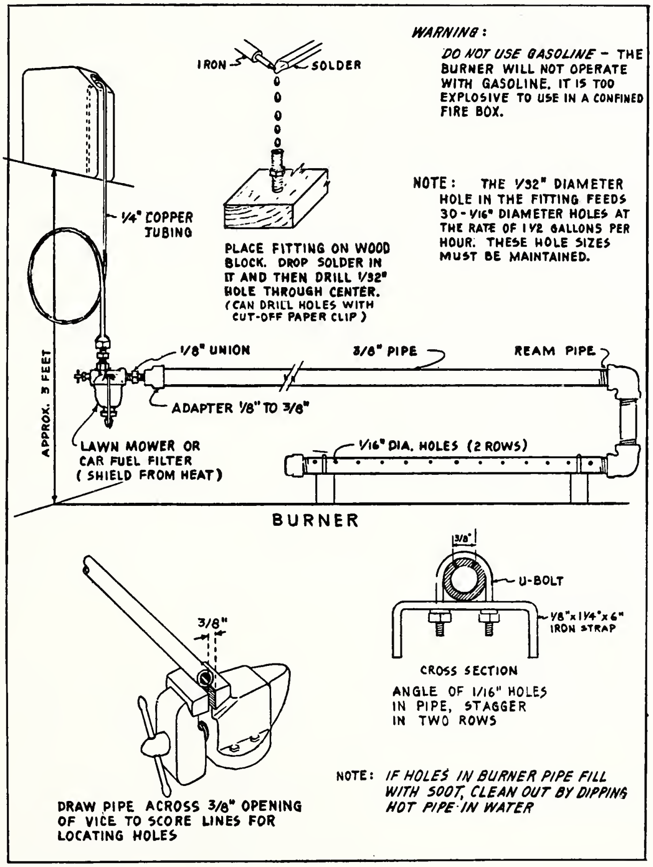
Stirring the garbage occasionally evens out the temperature of the garbage and shortens the cooking time. Stirring is simple with a small vat, although it is difficult with truck loads of garbage. Some trucks are equipped with a center shaft with agitator arms that stir up the top and bottom of the load. The shaft is slowly turned by a truck power take-off or an electric or gasoline motor.

The garbage should be cooled and fed to the hogs as soon as possible after it is cooked. Although it is not good to run cold water into the vat to cool the garbage, the garbage can be spread in a trough immediately after cooking instead of leaving it in the heating vat to cool.

Economics of Feeding Garbage to Pigs

Reliable cost data are essential to intelligent and profitable management. Information on the costs of every phase of operation—collection, cooking, veterinarian supplies and services, supplemental feed, labor, land, and maintenance of the farm—is necessary.

It is axiomatic that costs must be related to the selling price of the pigs. It is important to consider how much pork can be expected from



WARNING: *DO NOT USE GASOLINE* – THE BURNER WILL NOT OPERATE WITH GASOLINE. IT IS TOO EXPLOSIVE TO USE IN A CONFINED FIRE BOX.

PLACE FITTING ON WOOD BLOCK. DROP SOLDER IN IT AND THEN DRILL 1/32" HOLE THROUGH CENTER. (CAN DRILL HOLES WITH CUT-OFF PAPER CLIP)

NOTE: THE 1/32" DIAMETER HOLE IN THE FITTING FEEDS 30 - 1/16" DIAMETER HOLES AT THE RATE OF 1 1/2 GALLONS PER HOUR. THESE HOLE SIZES MUST BE MAINTAINED.

LAWN MOWER OR CAR FUEL FILTER (SHIELD FROM HEAT)

ANGLE OF 1/16" HOLES IN PIPE, STAGGER IN TWO ROWS

DRAW PIPE ACROSS 3/8" OPENING OF VICE TO SCORE LINES FOR LOCATING HOLES

NOTE: *IF HOLES IN BURNER PIPE FILL WITH SOOT, CLEAN OUT BY DIPPING HOT PIPE IN WATER*

Fig. 107. Oil can be used as fuel for "direct fire" cooking of garbage by converting the fire box.

each ton of garbage fed to a pig. It has been reported that hogs fed on cooked garbage gain more rapidly and produce more pork per ton of garbage than those fed on raw garbage. A weight gain of 1.44 pounds a day for the pig and a pork production of 193 pounds per ton of cooked military garbage have been reported. Experience in Canada shows that one ton of good quality cooked garbage produces an average of about 80 pounds of pork; each hog eats between 20 and 24 pounds of garbage daily and gains approximately one pound each day. Studies made in California indicate a yield of 70 to 75 pounds of pork per ton of cooked residential garbage. Records kept at the Kansas City penal farm piggery showed a pork production of about 100 pounds per ton of cooked commercial garbage.

Assuming the price of hogs is $20 a hundredweight, one ton of garbage delivered at a hog farm is worth from $15 to $39 gross to the hog raiser, depending on the type of garbage. Costs vary, however, and must be analyzed carefully for each case. For example, the haul from a city to the hog farm may be 10 miles or it may be 50 miles, with costs varying accordingly. Furthermore, costs of constructing a piggery that meets local standards vary considerably because local standards vary.

A group of hog feeders in an urban area in the northeastern part of the United States who raised approximately 54,000 pigs on 26 farms by feeding them raw garbage found that a capital investment of more than $400,000 was needed to process solid and liquid wastes produced on all of their farms in a manner that met local public health standards. Approximately 106 tons of solid wastes (wet basis) and 50,000 gallons of liquid wastes were produced each day.

Usually the cost of facilities should be paid off in approximately 10 years—the average life expectancy of the structures and equipment required for this type of operation. Costs are substantially less if secondhand equipment is used. Assuming that new equipment and facilities are used, however, and that two herds of hogs are fattened from 100 pounds to 250 pounds and marketed each year, the capital investment would amount to 25 cents per hundredweight over a period of 10 years.

Cooking garbage increases costs, of course. A cooker must be bought and maintained and men must be employed to operate it. Cookers come in all types and sizes and are frequently modified, so costs for them vary greatly as do labor and fuel costs.

The cost of garbage heat treatment in New Jersey in 1955 was about one-half that in Massachusetts, primarily because the equipment used in New Jersey was much more efficient and economical. The equipment used in New Jersey was similar to that recommended by the United States Agricultural Research Service and the United States Public Health Service. It had closely fitted lids on the trucks and efficient boilers. The equipment used in Massachusetts had poorly fitted covers or no covers, inefficient boilers and steam cleaners with no blow-off valves, and steam holes too large for economical operation. The cost of cooking garbage in 1955 ranged from $1 to $2 a ton; or at 70 pounds of pork produced for

TABLE 28

AVERAGE GARBAGE COOKING COSTS IN NEW JERSEY AND MASSACHUSETTS, 1955
(Per cubic yard: about 1,200 lbs.)

Cooking Method	*New Jersey*	*Massachusetts*
Direct-fire	—	$1.12
Small boilers and vat (less than 50 boiler hp)	$0.56	1.05
Larger boiler and vat	0.45	0.92

every ton of cooked garbage, the cost varied from $1.40 to $2.80 per hundredweight.

Proximity to a shipping point or meat packing plant is important to the hog raiser when his hogs have reached marketable size. In many localities, meat packers who are prejudiced against garbage-fed hogs penalize the hog raiser a cent or two a pound.

Fluctuations in the price of grain for feed are sometimes a cogent argument in favor of garbage-fed swine, since the supply of garbage and the price of it is constant, except for seasonal fluctuations.

Although the number of municipalities that have contracts to dispose of garbage for hog feeding has decreased rapidly, there are still a number of private operators who supply hog farmers with garbage from commercial establishments. Perhaps the best indication of the sound economics of feeding commercial garbage to hogs is the fact that the United States Department of Agriculture reported in June, 1960 that there were more than 9,000 garbage feeding establishments in the United States.

EFFECTS OF GARBAGE FEEDING ON REFUSE COLLECTION

If garbage is fed to swine there is considerable effect on the municipal refuse collection system. Garbage must be separated from other refuse before it is collected, separate collections must be made at different frequencies, and specially designed collection equipment is needed. It may also involve different collectors for different kinds of refuse.

Systems of Collection

Garbage to be fed to hogs is collected under one of three systems: by the municipality itself, by a private collector who contracts with the municipality to make the collections, or by private contractors who contract with companies and individuals to collect it.

At present, garbage collection is divided between municipal, municipal-private contract, and private contract methods. Household garbage is usually collected by municipal crews, but garbage from restaurants is often collected by private entrepreneurs who contract with the restaurants directly because there are large quantities that should be collected daily and because the rich quality of the garbage makes it valuable for

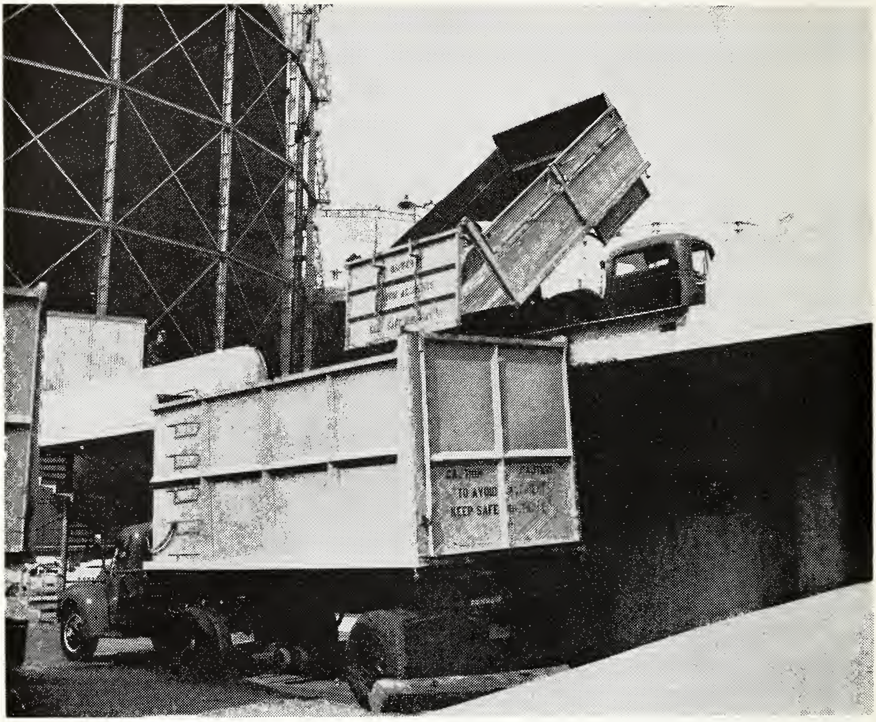


Fig. 108. Hog ranchers use semitrailers to get garbage from a refuse transfer station in Pasadena, California.

hog feeding. Furthermore, such collections often require special equipment, special timing arrangements, and special locations for containers.

Various local conditions determine who should collect the garbage, but the most important is whether there is a market for the garbage. Obviously, if garbage is fed to hogs or used in composting there is a market for it and private contractors frequently do at least some of the collecting. In many cities, separate collection of garbage by private collectors is a major advantage to the city because it makes municipal collections easier, helps eliminate odors, and cuts costs of disposal of other refuse by incineration or sanitary landfill.

Storage

Garbage that is to be fed to hogs should be stored separately from other refuse, although in the past many cities permitted householders to store them together. This made it difficult to use garbage as feed unless at the hog farm it was scattered over a large area and the hogs rooted through it, which created nuisances and unsanitary conditions. Since garbage must now be cooked, it is no longer stored with other refuse.

Garbage feeding to hogs also brought the practice of wrapping garbage into question. Garbage that is well wrapped is less likely to cause odors during storage than unwrapped garbage, it reduces the likelihood of flies breeding in it, and makes it easier to clean the container. Furthermore, in the North wrapping garbage prevents it from freezing to the container in the winter. On the other hand, if garbage is to be fed to hogs, wrapping is undesirable. It makes the cooking process difficult and adds a great deal of material to the garbage that has no nutritional value. A successful compromise is lining garbage containers with newspapers or paper bags.

The size of household garbage and refuse containers should be controlled by the city. The container should not be so small that the collection crew must empty many of them at any one residence but it should not be so large that it is too heavy for a collector to handle. Most garbage weighs from 800 to 1,200 pounds per cubic yard. Thus a five-gallon container and the garbage in it weigh from 25 to 45 pounds and a 55-gallon drum from 275 to 475 pounds. Household containers should be between 3 and 16 gallons. Containers for restaurants usually range from 20 to 32 gallons. If mechanical equipment is used to lift the container and dump the garbage into the truck, the capacity of containers may range from 3 to 16 cubic yards.

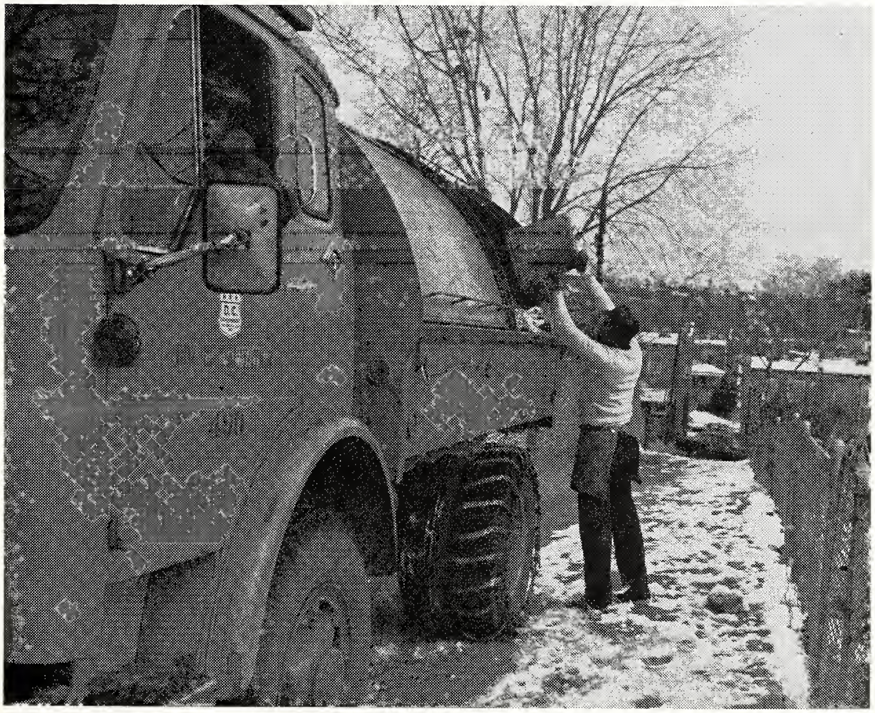


Fig. 109. If garbage is fed to hogs it must be collected separately. The District of Columbia designed and built its own garbage collection trucks.

Frequency and Kinds of Collections

If garbage is collected separately from other refuse, it is usually done because there is an advantage as far as the disposal method is concerned, because it is economical, or because the public wants it. In times of national emergency, several types of collections to separate salvage materials from other refuse may be necessary, regardless of the cost.

In Washington, D.C., for example, household garbage is collected separately by municipal trucks and is taken to a transfer station where some of it is ground and discharged into the sewerage system, some transferred to hog feeders' trucks, and some put on gondola cars and taken to District sanitary landfills. (District incinerators burn rubbish only, which makes operation of the incinerators easier than if they burned all kinds of refuse.) Similarly in St. Louis garbage is collected separately, which permits some of it to be transferred to hog-feeder trucks and some to be ground and put into the sewerage system at a centrally located plant.

Combined collection of residential refuse is usually considered more economical for the municipality than separate collections. That is not necessarily so, however. A final conclusion can be reached only after all factors and problems peculiar to the city are studied—costs of separate collections, savings from less frequent collection of rubbish, costs of special collection trucks for garbage, and the cost to the householder of separate containers.

Studies show that it requires less equipment and man-days to collect rubbish and ashes together once a week and to collect garbage separately twice a week than to collect all refuse together twice a week. If rubbish-ash collections are made weekly and garbage twice weekly one or several different disposal methods can be used.

There are, of course, other factors that must be considered: capital investment in collection and disposal plants and equipment on hand; availability of storage space for rubbish and ashes for a week; extra containers required for separate garbage storage; and seasonal changes in amounts of refuse. Seasonal changes can indicate, for instance, combined collections twice a week for four months of the year and once a week the other eight.

Some public works officials are convinced that most cities in the United States can collect well wrapped garbage mixed with rubbish once a week without causing health and nuisance problems. In Los Angeles County, for example, it was found that collecting garbage separately twice a week for disposal by hog feeders cost about $3.50 a ton more than it did to collect wrapped garbage with other refuse once a week. Thus separate collection of residential garbage in Los Angeles County represented a subsidy to the hog feeder and a loss to the community of some $600,000 a year.

If garbage is not well wrapped and is stored and collected separately, it is especially important that it be collected at least twice a week in residential areas during the warm, fly-breeding season. In some southern cities in the United States, garbage is collected three times a week. If the

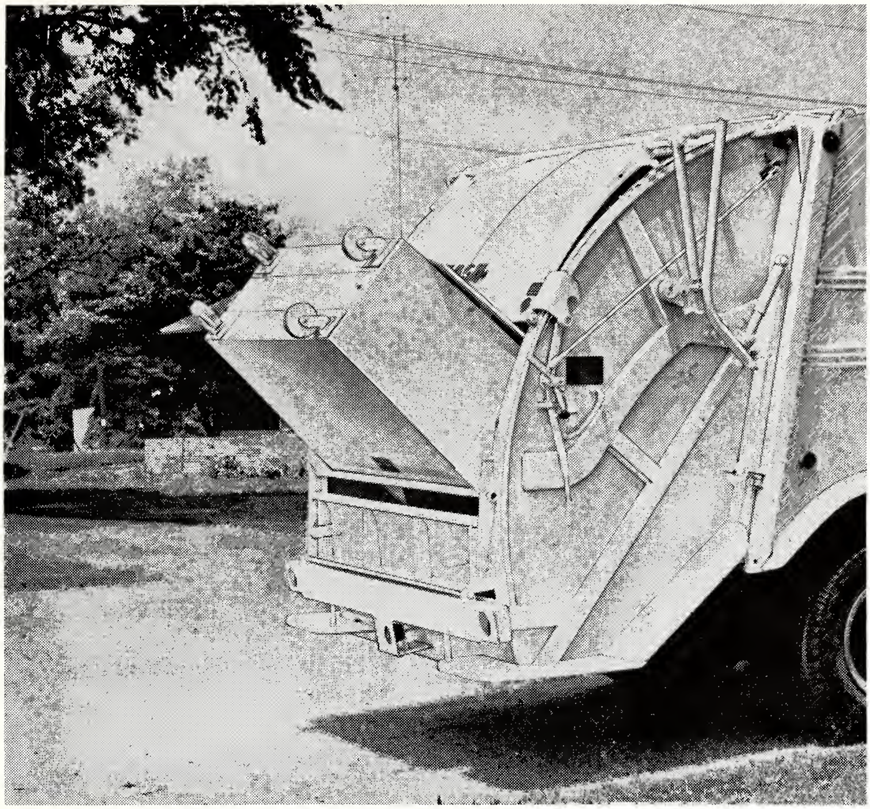


Fig. 110. If large quantities of garbage are collected from restaurants and institutions, it is sometimes worth while to use garbage receptacles that can be lifted and dumped by collection truck mechanisms.

garbage is fed to hogs, collections twice a week keep the garbage more palatable to the hogs and less likely to putrefy.

Table 29 shows that garbage is collected more frequently when it is collected separately. Two hundred and eight cities, or 66 per cent, reported at least twice-weekly garbage collections in residential areas in the summer and 154, or 50 per cent, reported twice-weekly collections during the winter. Other refuse was usually collected once a week.

Data collected in 1956 and compared with similar data collected in 1939 show that the practice of using residential garbage for hog feed is decreasing. Nevertheless, the practice of feeding garbage to hogs probably will continue to be economically sound for private haulers in many cities because of the quantity and quality of food wastes from restaurants and food processing companies.

Washington, D.C., where there is an unusual number of restaurants, is an example. The city is legally responsible for collecting all garbage twice a week, and does the actual collecting from residential areas. How-

Table 29

FREQUENCY OF REFUSE COLLECTIONS IN RESIDENTIAL AREAS OF 908 CITIES, SUMMER AND WINTER, 1955, BY KINDS OF REFUSE[1]

Kinds of Refuse	*Number of Collections*								
	6 or More Times a Week	*3 Times a Week*	*2 Times a Week*	*Once a Week*	*Once Every 2 Weeks*	*Monthly*	*Clean-up Drives Only*	*On Call*	*Variable or Combination*
SUMMER									
Combined refuse	3	27	261	215	6	. .	2	4	16
Garbage	2	37	169	92	3	. .	1	1	8
Ashes	1	2	14	38	10	3	2	13	8
Combined rubbish	1	3	9	32	9	6	14	12	7
Noncombustible rubbish	. .	2	4	22	9	6	2	6	6
Combustible rubbish	1	. .	4	17	5	3	2	10	4
Garbage and combustible rubbish	1	5	18	16	1	. .	1	3	1
Garden rubbish	1	1	11	38	7	7	27	49	15
All rubbish and ashes	. .	1	14	49	19	11	21	30	11
Dead animals	18	1	2	7	2	. .	. .	369	18
Bulky or extraordinary	2	1	3	6	3	2	19	67	17

Noncombustible rubbish and ashes	. .	1	2	11	2	5	. .	4	4
Garbage and combined rubbish	. .	2	6	3	. .	. .	. .	. .	55
WINTER									
Combined refuse	3	22	238	236	4	. .	. .	5	17
Garbage	3	21	130	140	3	1	1	2	7
Ashes	1	3	17	50	7	3	. .	16	8
Combined rubbish	1	2	5	33	9	6	7	12	8
Noncombustible rubbish	. .	2	4	24	8	6	2	6	6
Combustible rubbish	2	. .	3	18	5	3	1	10	4
Garbage and combustible rubbish	1	4	14	21	1	. .	1	2	1
Garden rubbish	1	. .	8	31	6	5	15	46	11
All rubbish and ashes	. .	1	12	54	20	10	9	30	11
Dead animals	18	1	1	9	1	. .	. .	352	17
Bulky or extraordinary	2	1	3	4	3	2	11	68	16
Noncombustible rubbish and ashes	. .	1	2	12	3	4	. .	4	4
Garbage and combined rubbish	. .	1	5	6	. .	. .	. .	. .	49

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[1] Data from 1956 survey by the American Public Works Association.

TABLE 30

TONS OF GARBAGE COLLECTED ANNUALLY IN THREE CITIES, 1952-1955, BY MONTHS

Year	*Jan.*	*Feb.*	*March*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total*
LOS ANGELES													
1952	14,116	12,265	13,725	13,654	13,570	15,133	17,061	16,507	15,478	14,527	13,012	14,498	173,546
1953	13,074	11,871	13,584	13,027	13,168	15,003	16,935	15,741	15,739	14,469	13,267	13,572	169,450
1954	13,026	11,471	13,050	12,253	12,829	13,749	16,804	15,020	14,164	12,748	12,920	13,022	161,056
1955	12,901	11,905	12,506	12,398	13,114	13,510	15,264	16,551	14,250	13,024	12,919	12,546	160,888
Avr.	13,279	11,878	13,216	12,833	13,170	14,349	16,516	15,955	14,908	13,625	13,030	13,410	—
PHILADELPHIA													
1952	12,200	11,200	11,900	12,200	12,000	12,300	13,700	14,500	14,100	12,600	11,800	11,900	150,300
1953	11,500	10,600	11,700	12,400	13,700	14,200	14,400	14,900	14,200	12,500	12,300	12,600	155,000
1954	12,200	12,400	12,800	12,800	13,300	14,500	14,600	15,200	14,900	14,000	13,500	12,800	163,000
1955	12,500	12,400	13,100	13,400	13,900	14,400	15,500	16,900	15,600	14,200	13,500	12,800	168,200
Avr.	12,100	11,625	12,375	12,700	13,225	13,850	14,550	15,375	14,700	13,325	12,775	12,525	—
WASHINGTON, D. C. (residential garbage only)													
1952	3,686	3,415	3,575	3,649	3,729	4,150	4,763	4,686	4,567	3,772	3,325	3,687	47,184
1953	3,634	3,168	3,649	3,631	4,132	4,539	5,055	4,989	4,397	3,717	3,644	3,751	48,306
1954	3,326	3,073	3,676	3,681	3,730	4,497	4,799	4,943	4,630	3,812	3,633	3,489	47,289
1955	3,274	3,047	3,489	3,286	3,601	3,928	4,762	5,176	4,119	3,496	3,569	3,232	44,979
Avr.	3,480	3,176	3,597	3,562	3,798	4,278	4,845	4,949	4,428	3,699	3,543	3,585	—

ever, because of the frequency and the type of service needed for the many restaurants and the quality of the garbage, private collectors and hog feeders in the Washington area contract with the restaurants and under supervision of the District government collect and dispose of restaurant and commercial garbage. More than 40,000 tons of garbage a year are handled in this manner. Collection of residential garbage in 1954 and 1955 cost the District government $12.88 a ton. At $12.88 a ton, it would have cost the District more than a half-million dollars to provide equivalent collection services for restaurants, plus the cost of disposal.

Those experienced in setting up and operating refuse collection and disposal systems are aware that local factors control the systems used by a city, and it is important to realize that the system used in Washington is not described here as the basis for determining the merits of collection and disposal systems. It is an example of how local conditions determine what collection and disposal systems are most appropriate for a city. A decision must be based on an analysis of local conditions.

Collection Equipment

The separate collection of garbage from other refuse requires equipment designed for the job. Because of the relatively high density of garbage compared with rubbish and the relatively small amount of residential garbage per capita (about one-eighth of a gallon per capita per day), a truck with a heavy-duty chassis and a 5- to 10-cubic yard body is usually ample. The body should be covered, watertight, and so constructed that garbage can easily be unloaded from it.

Public Acceptance

Regardless of costs, any public service is successful only if the public likes and accepts it. This is especially true of refuse collection and disposal systems because they affect every resident of the city. The public wants and usually demands prompt services that are perhaps best described as "the simpler the better."

It is relatively easy to change a collection system that requires that garbage be stored separately from other refuse to one in which combined storage is permitted. But the opposite is not as easy. Unless there are special circumstances, such as a national emergency, getting the public to change from a combined refuse collection system to a separate one is an almost impossible task. In fact, even in a national emergency, a persuasive public relations program is necessary to get the public to separate salvageable refuse from the rest of it. Cities that now have separate collection systems but may be considering a combined system will find it is not difficult to decide one way or the other on an objective, economic basis.

Layout and Design of Piggeries

Although only a few cities have ever directly operated pig farms to dispose of refuse, all cities that dispose of garbage to hog feeders—directly or indirectly—have a responsibility to see that farms on which hogs are fed garbage are well built, regulated, and properly operated. State, county, and local government agencies usually have an interest in them—enforcement agencies, health and sanitation agencies, planning and zoning boards, and agriculture departments.

All too often ordinance provisions covering piggeries are vague and confusing and responsibility for enforcement is widely scattered. However, if several different agencies and departments are involved, their functions can be consolidated. In Los Angeles County, for example, the county livestock inspector, the county health department, the county engineer, the regional planning commission, and the state livestock disease control bureau were all involved in regulation and inspection of pig farms. To avoid duplication of services, the Los Angeles County Livestock Department was designated to carry out and enforce the regulations of all the agencies.

Preliminary Planning

Before a prospective pig feeder selects a site for his farm, he and the contractor who will build it should—to acquaint themselves with all requirements—consult local agencies responsible for regulation. Once the site is selected, it should be inspected by all responsible officials. Plans for the piggery should be submitted to the control agency for approval before construction is started. (Most building codes require submission of plans when application for a building permit is made.)

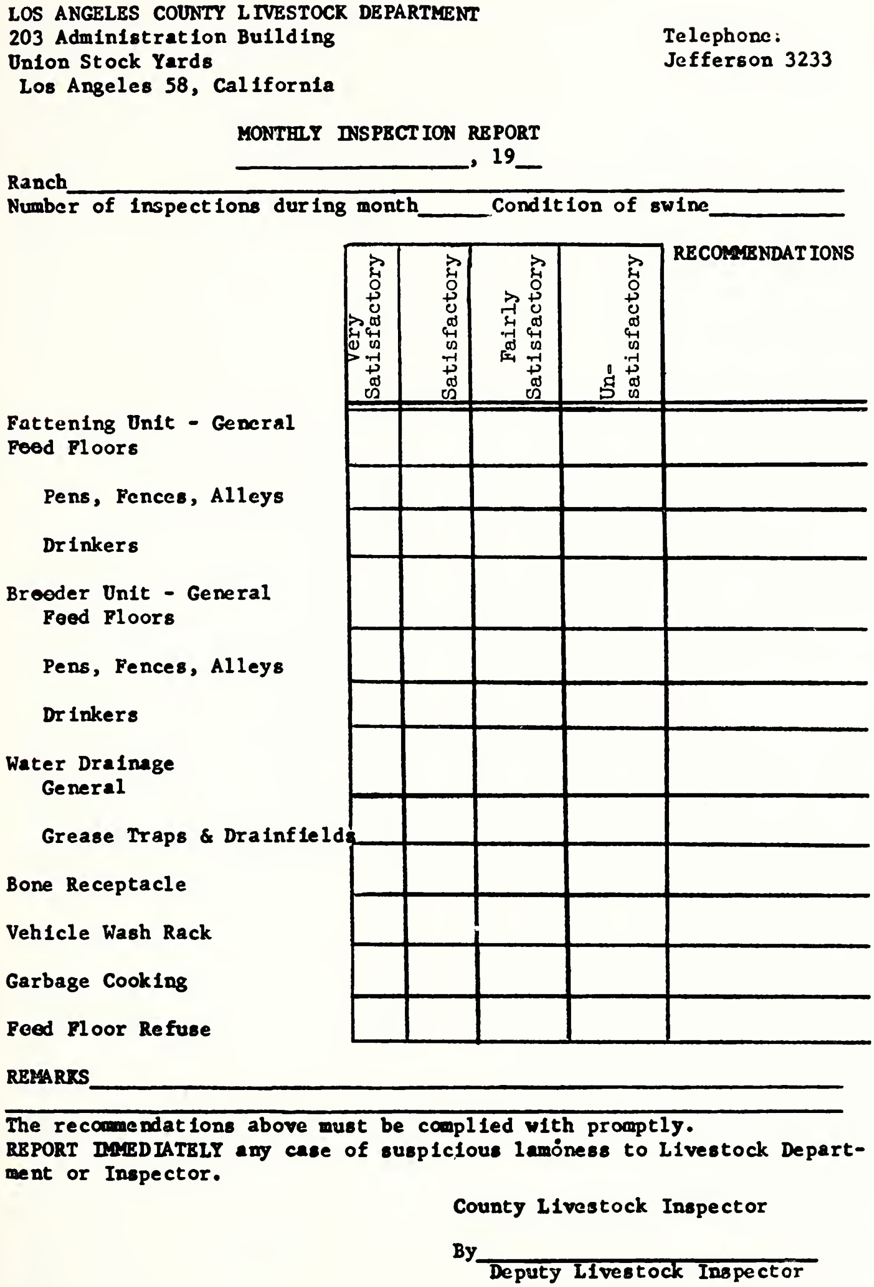
The responsible agency should inspect each phase of the construction so that violations can be prevented or easily corrected before the piggery is completed. Once the ranch is in operation, it should be inspected routinely and a copy of the written report of conditions given to the owner. Figure 111 is an example of such a report.

A suitable location is of prime importance if a pig farm is not to be declared a nuisance. It should be accessible in all kinds of weather; be well drained, either by natural or artificial means; and have an adequate supply of potable water.

Basic Design

Piggery design obviously depends on the size and type of operation, but also to a large extent upon climate. If snow and freezing temperatures are usual, design problems are greater than if the climate is mild the year around. Feeding and housing areas must be enclosed, as must areas for cooking garbage and for storing vehicles and implements. Provisions should be made for artificial ventilation when doors and windows must be kept closed. If the climate is especially cold, heat should be considered for areas where the pigs are housed, particularly if early spring and late fall or winter farrowing is advantageous.

The farm usually consists of feeding and fattening units, farrowing units, breeding sections, and dry sow pens. Garbage cooking units, parking lots, garages, storage areas, and waste disposal facilities are accessory sections.



LOS ANGELES COUNTY LIVESTOCK DEPARTMENT
203 Administration Building
Union Stock Yards
Los Angeles 58, California

Telephone:
Jefferson 3233

MONTHLY INSPECTION REPORT

__________________, 19__

Ranch____

Number of inspections during month_____Condition of swine__________

	Very Satisfactory	Satisfactory	Fairly Satisfactory	Un-satisfactory	RECOMMENDATIONS
Fattening Unit - General **Feed Floors**					
Pens, Fences, Alleys					
Drinkers					
Breeder Unit - General **Feed Floors**					
Pens, Fences, Alleys					
Drinkers					
Water Drainage **General**					
Grease Traps & Drainfields					
Bone Receptacle					
Vehicle Wash Rack					
Garbage Cooking					
Feed Floor Refuse					

REMARKS____

The recommendations above must be complied with promptly.
REPORT IMMEDIATELY any case of suspicious lameness to Livestock Department or Inspector.

County Livestock Inspector

By__________________________
Deputy Livestock Inspector

Fig. 111. City, county, and other officials are often responsible for inspecting farms on which hogs are fed garbage. The Los Angeles County Livestock Department uses this form to report on inspections of such farms.

The farm should be designed to provide "production line" movement of pigs from the breeding section to the farrowing units and through the feeding and fattening units to the market.

Feeding and Fattening Units. Feeding and fattening units are those in which the pigs are kept from the time they are weaned to the time they are ready for market.

Feeding floors and platforms where garbage is fed to the pigs must be constructed of concrete or other equally impervious material. They should be smoothly finished for easy cleaning, well-drained into grease traps and drainfields, and have 18-inch "rat walls" on all sides to prevent rats from getting in. Approximately 5 square feet of floor area should be allowed for each animal. A feeding floor 10 by 50 feet is commonly used for 100 pigs.

The feeding area should be enclosed with solid concrete or fenced with chain link or wood on steel posts set in concrete curbing. Chain link or wood fencing on steel posts set into a concrete curb may also be used around the edge of the feeding floor. The curbing should be 8 to 12 inches high and should be reinforced and fastened securely to the feeding platform.

A feeding floor can be adequately drained by allowing a 1-foot drop for every 100 feet of floor. The runoff is collected in a gutter at the end of the floor and passed through screens to remove solid material. It is then directed through a grease trap and finally spread underground through a drainfield.

Design of drinking equipment for the feeding unit varies. All drinkers should be equipped with a float-type valve. They must be easy to clean, be set on a concrete platform to provide approximately 6 feet of floor space on each side, and the platform so constructed that overflow water drains onto the feed floor. They should not be large enough to allow animals to lie in them; a space large enough for the pigs to put their snouts in is sufficient.

Pens should be at least 50 feet by 150 feet for 100 hogs and larger if possible. Fences should be made of wooden panels or chain link set in concrete. Chain link fencing is especially desirable because it is difficult for pigs to root up. All pens should have gates that can be latched between them and the feeding floor so that the animals can be shut into the pens while the floor is being cleaned and while they are being fed. When closed, the gates should be completely off the feeding floor to prevent damage to them during the cleaning operations. Easy access should be provided in the back of each pen for cleaning.

Construction of shelters for the feeding units varies, depending on the weather, but they are usually built of wood with corrugated iron, aluminum, or tar paper roofs. One shelter approximately 1½ times the area of the feeding floor can usually serve two pens. It should be high enough to permit a cleaning vehicle, such as a skip loader, to enter. If the sides of the shelter are hinged they can be closed during inclement weather.

Pigs often defecate and urinate immediately after feeding so that if they are forced to enter the shelter from the rear, the shelter can be kept

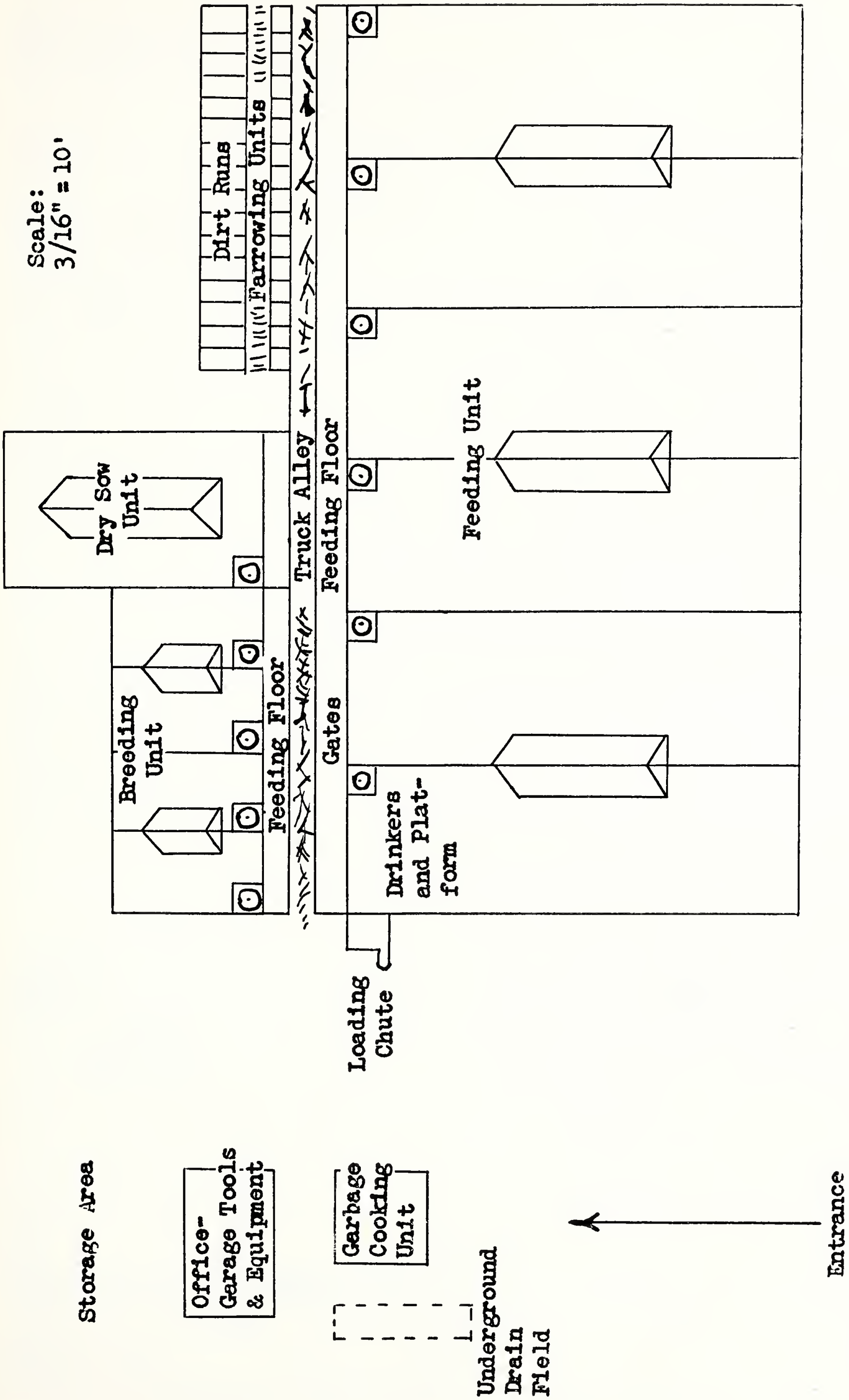

Scale:
3/16" = 10'
Dirt Runs
Farrowing Units
Truck Alley
Feeding Floor
Feeding Unit
Dry Sow Unit
Breeding Unit
Feeding Floor
Gates
Drinkers and Platform
Loading Chute
Storage Area
Office-Garage Tools & Equipment
Garbage Cooking Unit
Underground Drain Field
Entrance

Fig. 112. Hogs can be fed garbage on a "production line" basis if the piggery is efficiently laid out.

cleaner, because the animals will usually relieve themselves before entering. Crushed rock or cinders 1½ to 2 feet deep are excellent for the shelter floor and provide good drainage. Cement floors are cold and hard and require a large amount of bedding material.

Farrowing Units. Many pig farmers find that they cannot always buy suitable feeder pigs and therefore must breed their own.

The kind of construction used for farrowing units probably depends more upon the weather than does any other part of the farm. Breeding must be carried on throughout the year to produce feeder pigs regularly. During freezing weather, new-born animals must be kept dry and warm or the mortality rate is disastrously high. Farrowing units consisting of a

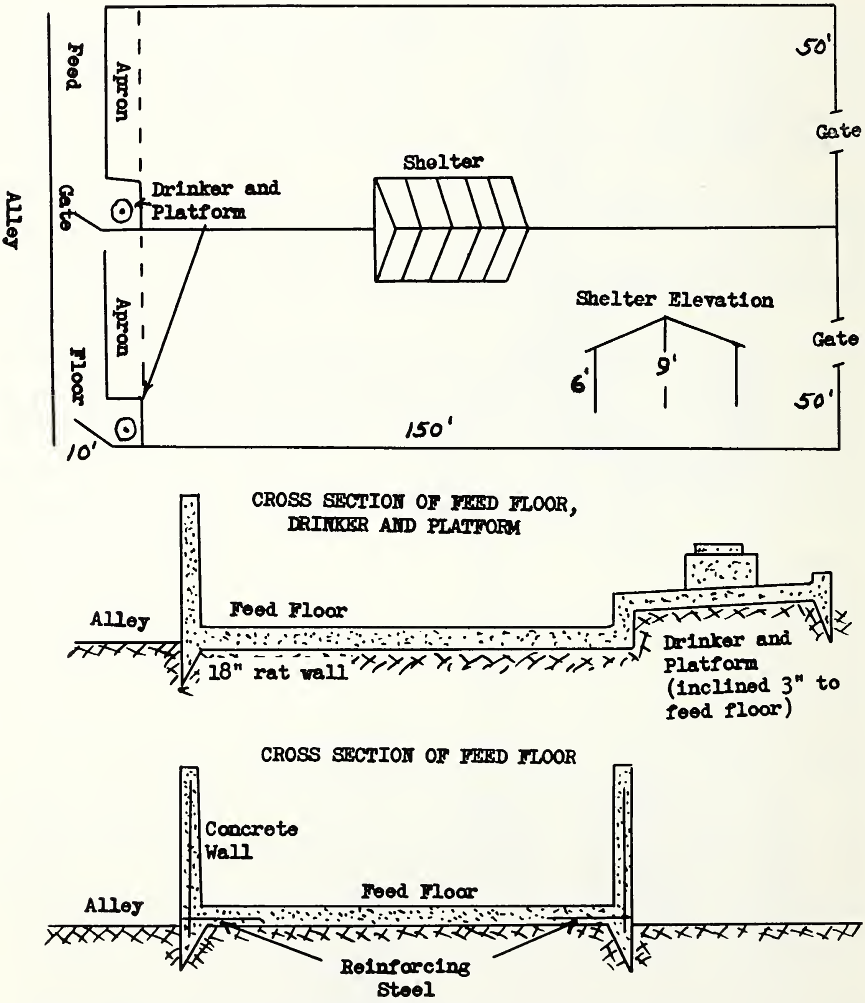

Alley
Feed
Apron
Gate
Drinker and Platform
Apron
Floor
10'
Shelter
150'
50'
Gate
Shelter Elevation
6'
9'
Gate
50'
CROSS SECTION OF FEED FLOOR, DRINKER AND PLATFORM
Alley
Feed Floor
18" rat wall
Drinker and Platform (inclined 3" to feed floor)
CROSS SECTION OF FEED FLOOR
Concrete Wall
Alley
Feed Floor
Reinforcing Steel

Fig. 113. Cross section of a feeding unit of a piggery.

feeding floor, shelter, and dirt run, should be big enough to accommodate a sow and her litter.

Farrowing floors are similar to floors in the feeder unit except that they are smaller (8 feet square), and, depending on climate, they may or may not be covered. Gates rather than division fences are built between each feeding floor for easy cleaning. Shelters can be either single or double. Double shelters have two rows of units with an alleyway between them. Floors in the shelters should also be 8 feet square and should be of concrete so that they can be cleaned easily.

Protectors, made of two-by-fours placed about 6 inches from the floor and 8 to 10 inches from the wall, should line all walls of the brooder to prevent the sow from crushing the small pigs. A warmer for the baby pigs can be built in a corner by boarding it across to form a triangle 8 to 10 inches high. The front is not enclosed so the baby pigs can easily get to the sow; the top is hinged so it can be opened. An electric light bulb in a one-gallon tin that hangs down into the enclosure from the top provides the heat.

Wood, coal, or gas stoves may be used to heat the farrowing unit if the weather is especially cold. In recent years, radiant heat has been used. Pipes are embedded in the floors and steam or hot water is run through. If the units are heated, however, the pigs must be protected against sudden changes in temperatures because sudden changes make them susceptible to pneumonia and other infections.

Good ventilation is especially important in farrowing units. The partitions between units should not be more than 4 feet high and should have enough openings for air to circulate. The ends of the shelter should be so constructed that they can be opened in good weather and closed in bad weather. Roof ventilators equipped with dampers are often practical.

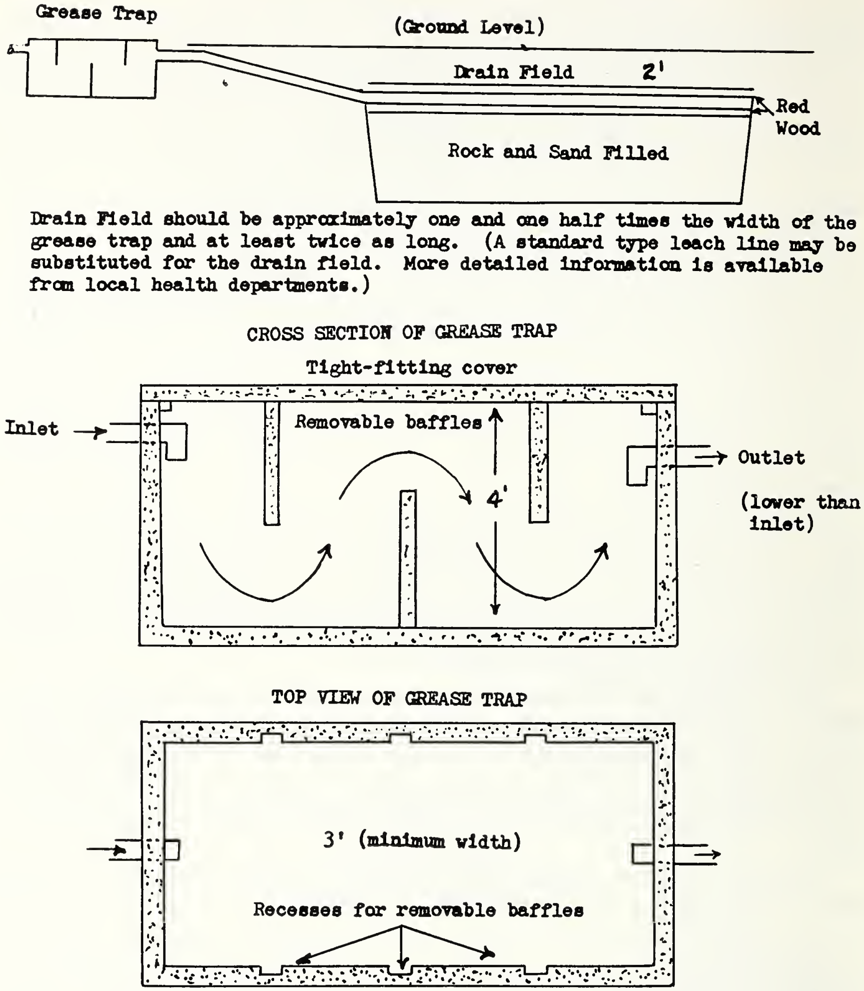
Straw, shavings, or other bedding material must be provided to help keep the farrowing units warm, dry, and clean.

Accessory Units. Many accessory units must be considered in the construction of a hog farm on which the animals are fed garbage. One is the garbage cooking area, which is discussed in the section on treating garbage.

A suitable area for cleaning and washing vehicles is near the cooking platform, where hot water and steam are available and refuse from the trucks can be washed into the cooking unit drainage system.

Disposal of wastes from the feeding floor is one of the worst problems of piggeries. Disposal is influenced by: (1) the amount of wastes, (2) the amount of space available, (3) the season of the year, (4) proximity of the piggery to dwellings.

Waste from feeding floors is excellent fertilizer if it is properly processed. If space and other conditions permit, it can be thinly spread over a large area and dried quickly, keeping odors to a minimum. If space is not available and weather does not permit drying, it can be composted or buried. If it is hauled away to be composted, strong odors create a



Grease Trap
(Ground Level)
Drain Field
2'
Red Wood
Rock and Sand Filled

Drain Field should be approximately one and one half times the width of the grease trap and at least twice as long. (A standard type leach line may be substituted for the drain field. More detailed information is available from local health departments.)

CROSS SECTION OF GREASE TRAP

Tight-fitting cover
Inlet
Removable baffles
4'
Outlet
(lower than inlet)

TOP VIEW OF GREASE TRAP

3' (minimum width)
Recesses for removable baffles

Fig. 114. Cross section of a grease trap and drain field for disposing of liquid wastes at a piggery.

real nuisance for nearby residents. As a last resort wastes can be buried by a cut and fill operation.

Large quantities of bones are usually found in feed floor refuse. Since they can be sold, they are usually separated from the other refuse and stored. The area for bone storage should be screened, be at least 18 inches off the ground, and be kept sanitary at all times.

The best place to store materials is at the rear of the farm. Boards, posts, and similar materials should not be stacked on the ground, however, because if they are rats can easily use them for harborage.

9 COMPOSTING

Composting is the biochemical degradation of organic materials to a sanitary, nuisance-free, humus-like material. Modern scientific composting has been described as a rapid but partial decomposition of moist, solid, organic matter by the use of aerobic microorganisms under controlled conditions.

Although at the end of the 1950's there were only a few small composting plants in which municipal refuse was treated in the United States, experiences in Europe and with experimental operations in the United States indicate that capital and operating costs of a compost plant may, under favorable conditions, be similar to costs for an incinerator. The major advantage of the process appears to be that it produces a potentially marketable and useful product. However, unless some economically beneficial use is actually made of the end product, composting will be of limited value as a means of municipal refuse disposal.

There is considerable controversy among public works officials over composting as a method of refuse disposal. A lack of confidence in the process is understandable and to some extent justified in view of the failures of certain widely heralded composting plants that in the past have processed refuse for cities in the United States.

Actually, little scientific investigation was made of composting of municipal refuse in the United States before 1950. It was largely through the efforts of the University of California, Michigan State University, and the United States Public Health Service that research was begun. As a result, the basic principles of composting refuse for municipalities are now sufficiently well understood to effectively use the process under favorable circumstances on a full-scale basis. Although a decision to use the method should be approached with caution, it is possible that at least at times the economic advantages of it will be considerable. If composting is to be a successful method of disposal, however, several factors must be considered. It should be decided upon only after an engineering survey is made to determine if it is economically and scientifically feasible under local conditions; the plant and equipment should be designed on the basis of modern, scientific principles; the plant should be operated on a scientific basis; and there should be a satisfactory market for the product.

There is reason to believe that early in the development of agriculture, man learned to use leaf mold, animal manure, decayed fish, and other decomposed organic matter in husbanding his crops. However, only in quite recent years has the biochemistry of composting been sufficiently well understood to apply it to municipal refuse disposal problems.

Perhaps the first significant development in composting as an engineered process took place in India in 1925. At that time Sir Albert Howard, in collaboration with others, systematized the procedure by which farmers and gardeners had for many centuries produced humus for use on the soil. Sir Albert's process, known as the Indore process because of the country in which it was developed, is simple. Organic wastes such as garbage, straw, and leaves alternated in layers with night soil, sewage sludge, or animal manures were put into pits or trenches two to three feet deep or piled on open ground to a height of about five feet. The mass was turned twice during a period of six months; and the drainage was utilized on the pile to keep the compost moist. Because the process uses principally hand labor, it has been widely used where manpower is cheap and plentiful.

In some places the Indore process has been modified, chiefly by turning the compost material more frequently to hasten the aerobic action and to lessen the odors. The Indian Council of Agriculture Research improved the method and has used it widely under the name of the Bangalore process.

Composting processes in which the principal objective was to dispose of refuse rather than to produce a humus were begun in the early 1920's. These processes, several of which have been patented, were aimed at rapid production of compost, mechanized handling of materials, and less objectionable methods.

The most important of the early patented processes was developed by Dr. Giovanni Beccari of Florence, Italy, in 1922. It combined an initial anaerobic fermentation with a final stage in which decomposition proceeds under partially aerobic conditions. A modification of the Beccari process, known as the Verdier process, provided for the recirculation of gases or drainage liquors. A further modification of the process was made in 1931 by Jean Bordas, who sought to eliminate the anaerobic stage.

The first full-scale composting plant in Europe and at the time the largest in the world was begun in the Netherlands in 1932 by a non-profit utility company formed by the government for the disposal of city refuse. It used the van Mannen process, a modification of the Indore process, in which refuse is composted in large windrows.

The Dano biostabilizer system and the rasping system of windrow composting are the two most widely used processes in Europe. The Dano system consists of a single slowly revolving, horizontal cylinder that holds the material from one to five days. Material is finished by windrowing, with or without turning, in two to four weeks. The rasping system involves grinding the refuse before the composting process is started and turning the compost piles during a three- to six-week period (instead of sprinkling the piles and composting it for four to eight months, as had been done previously).

By early 1960 there were 25 Dano biostabilizer plants and 12 rasping system plants in use or under construction in Europe, most of them

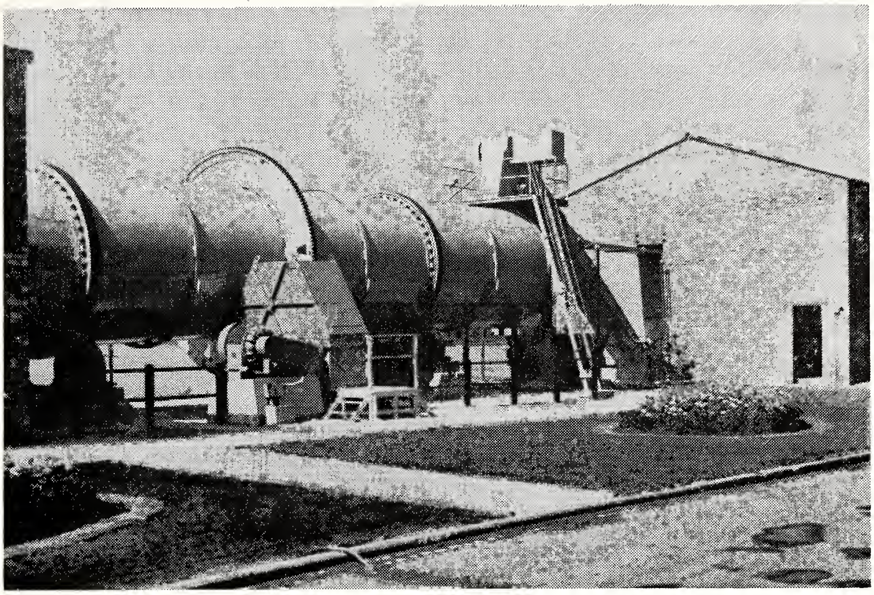


Fig. 115. Typical 25-ton-a-day Dano composting plant in Europe. Refuse is kept in digester five days followed by two to four weeks of windrowing in the open.

built in the 1950's. These systems provide for more rapid composting than former methods because aerobic decomposition is more closely maintained during the process. Furthermore, special equipment for composting refuse was developed. (In the United States attempts have been made to adapt equipment used in other processes for refuse composting.)

There are also a number of single installations of cell-type or enclosed composting involving the intermittent disturbance principle: the John Thompson system plant at Jersey, Channel Islands, Great Britain, and one in Bangkok, Thailand; the Dumfriesshire system plant at Kirkconnel, Scotland; the Tollemache system plant at Mabelreign, Southern Rhodesia, South Africa; and the Calais system plant at Calais, France. The same principle is used in plants in the United States: the Riker system at Williamston, Michigan, and the Naturizer system at Norman, Oklahoma. These systems are not as efficient as those providing continuous mixing, aeration, and particle size reduction but they may be somewhat more efficient than windrow composting.

Composting processes were not developed in the United States at the same time they were in India and western Europe. Before 1950 only a few municipal refuse disposal officials gave attention to advocates of composting. Without a process of proven worth or even a basic understanding of the science of composting the advocates of composting could at best offer only enthusiasm. Most often they tried to sell an untried process or a special inoculum. Most claimed that their process would be profitable. However, little came of such efforts because no well tested process was offered. Besides, city officials in the United States consider disposal the problem—not making a profit—and they are reluctant to become involved in uncertain composting ventures. Nevertheless, a few attempts were made to import European methods. The Beccari process and its modifications, tried for a short time in Scarsdale, New York, in the late 1920's did not prove adaptable to municipal composting of refuse on a large scale and under conditions peculiar to the United States, although there were a number of plants in Europe by that time. Furthermore, garbage and other putrescible components of refuse in United States cities, together with environmental problems, also made impractical any simple adaptations of the procedures used so successfully in the van Mannen system.

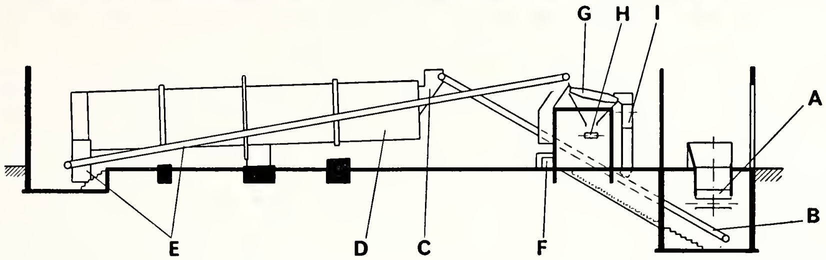
To suit United States conditions it was thought desirable that composting be done mechanically in completely enclosed structures. A multiple-deck digester of the silo type was patented in 1939. Aeration involved a combination of rotary plows and air flues, the material moving downward from deck to deck on a continuous flow basis. Some work was done in a pilot plant but mechanical weaknesses were encountered. Furthermore, advocates of the process claimed that it was dependent upon the use of a secret and expensive inoculum.

In 1949 a process patented in the United States was introduced in which shredded organic matter was put into a fully enclosed, semimechanized digester intended to produce compost in 28 days under aerobic conditions by intermittently dropping the material from one level to another, which permitted contact with the bases of decomposition—a salient feature of the process. Reportedly, each of four small experimental plants had technical problems, including difficulty in keeping the material aerobic, and was closed.

The University of California in 1951 began a two-year study of the principles of aerobic composting, which terminated in a pilot demonstration carried out in cooperation with the City of Berkeley. The study went into the feasibility of composting refuse using open windrows. The process requires sorting and shredding the refuse, putting it in windrows five to six feet high, and turning the material about three times in a 15- to 21-day composting period.

While the University of California was making its study, the Compost Corporation of America began a pilot plant operation in Oakland, California. During the year it was in operation, many of the problems of shredding refuse and handling compost were uncovered, the lack of justification for adding inoculum was demonstrated, and the practicality of the windrow method as recommended by the university was verified for California conditions. The pilot project led to the design of a workable plant but local problems prevented its construction.

Between 1953 and 1956 a team of researchers at Michigan State University conducted extensive laboratory and field experiments on the



A = *receiving hopper*
B = *conveyor belt for crude refuse*
C = *device for feeding material into Bio-stabilizer*
D = *Bio-stabilizer*
E = *conveyor belts for transferring material from Bio-stabilizer to screen*
F = *hopper and equipment for cans and scrap metal*
G = *screen*
H = *conveyor belt for taking away screened compost*
I = *chute for tailings from screen*

At this plant, 20 tons of refuse, with sewage sludge added, are processed per day.

Fig. 116. Diagram showing composting process in a 25-ton-a-day Dano plant.

composting of municipal wastes. The effects of temperature, pH, moisture, and other variables of the composting process were studied and solutions to problems were investigated by actually composting four to five tons of garbage a day from the City of East Lansing. An eight-deck silo type digester was operated for two years after which a three-deck horizontal mechanical digester was developed. Windrowing of ground garbage was aided by a front-end loader and a shredder. Experiments using forced air, with or without turning, in barrel and bin-size units led to the development of processes described as "modified windrow," "bin," and "area" composting. Some of the details are reported in other parts of this chapter.

The United States Public Health Service initiated two research projects on composting in 1953—one in Savannah, Georgia, and the other in Chandler, Arizona, near Phoenix. Both have contributed substantially to the basic knowledge of composting. The Phoenix studies included the development, construction, and operation of a 70-ton-a-week experimental plant at Chandler in which aeration, bin, and windrow composting was used. The operation of this plant produced substantial information on the cost of refuse grinding and other material handling aspects of composting. The Savannah project has made excellent contributions through its basic laboratory scale research.

In 1956 a widely advertised composting plant with a capacity of about 100 tons a day began operation at McKeesport, Pennsylvania. Apparently efficient grinding and mechanical handling devices were used in the plant, but after a year's operation the plant was closed, reportedly because of technical problems and economic difficulties.

A Dano plant was built near Sacramento, California, in 1957 to treat 40 tons of refuse a day with a 48-hour retention period. By 1959, the plant was processing 80 tons a day with a 24-hour retention period. The "green" compost produced required further maturing by windrowing or removal for direct curing on the farm.

A 40-ton-a-day mechanical digestion plant constructed by the Naturizer Corporation in Norman, Oklahoma, in early 1959 employs primary and secondary grinding and large digesters in which the ground material is moved by pan-type conveyers through six decks. This same principle was used on a smaller scale for composting stockyard manure and ground leaves in Toronto in 1954 and 1955. The original Naturizer design was abandoned in favor of horizontal rotating agitators, reported to produce more efficient and higher rates of digestion. It is reported that a local adaptation of this later design proved biologically successful but mechanically deficient in a 20-ton-a-day plant built in Kobe, Japan, in 1956.

The Value of Compost

Reliable data are available to prove that many farmers in the United States have worked the soil to such an extent that organic matter in it is depleted and productivity of the soil is greatly reduced. In some areas productivity has been cut by as much as 50 per cent. Sometimes a farmer has added chemical fertilizers to the soil, but soil scientists point out that this may ultimately do more damage than good. They say that the solution is to replace the organic matter in the soil. There are two major ways that this can be done: (1) plant green crops and plow them under, and (2) add compost or animal manure in one form or another. The farmer, however, must weigh the costs of purchasing and spreading compost against the costs of raising a crop and plowing it under. He probably spends from $20 to $25 a ton for the organic matter produced by raising and plowing under a cover crop—often called "green manure."

The value of organic matter can also be evaluated by actually adding it to crops and determining the increase in yield. Although the increase in yield is frequently the only factor evaluated, there is also reported to be a marked increase in the quality of the crops—in protein, vitamin, and mineral content.

Addition of organic matter to the soil is reported to have several benefits:

1. It markedly improves the physical properties of the soil; makes it easier to till, more porous, and easier to keep aerated. It also helps the soil absorb precipitation. Organic matter holds water like a sponge (it retains up to 300 per cent moisture by weight) so that in periods of drought a field that contains a large amount of organic matter may be productive when soil without it is valueless. Organic

matter also supports earth worms, which in turn keep the soil porous and improve aeration. The worm holes increase percolation during heavy rains, which reduces runoff and soil erosion.

2. According to the results of tests run in California, organic matter in soil reduces the amount of chemical fertilizer required by as much as 40 per cent. This is largely due to the mechanics of leaching or the prevention of leaching. If organic matter is present in the soil, water does not wash away chemical fertilizers as it does in barren soils.
3. Experiments by soil scientists indicate that the presence of organic matter is a prerequisite to healthy biological activity of the soil, and healthy biological activity stimulates plant growth, especially the roots. Roots have been known to grow eight times as fast in soil in which there is a lot of organic matter as it does in soil in which there is little or no organic matter.
4. Healthy biological activity is also reportedly important in the breakdown of insoluble mineral compounds such as the phosphates, which are required for plant growth.
5. Soluble nitrogen used as a fertilizer can be easily leached away. In the presence of organic matter and biological activity, however, a portion of this soluble nitrogen is converted into organic nitrogen of the microorganisms' bodies. As the microorganisms die, the nitrogen again becomes available to the plant roots. In the interim, it is less likely to be lost by leaching or to the atmosphere as ammonia.
6. The same phenomenon occurs with phosphorus. Tests show that about 95 per cent of soluble phosphorus can be converted into organic bodies and living protoplasm and released slowly to the plant as an organic complex, thus reducing loss by leaching.

Advantages and Disadvantages

It is difficult to tell exactly what the advantages and disadvantages are of a disposal method that has considerable potential but has not been adequately used and proven on an operational basis in the United States. There apparently are, however, advantages and disadvantages, if experiences with pilot plants in Europe and in the United States during the 1950's are evaluated.

Advantages

1. A composting plant produces a useable end product that may be sold, thus either paying for, or at least reducing, costs.
2. Composting can be used to dispose of many industrial wastes such as those from meat packing plants, paper mills, saw mills, tanneries, stockyards, and canneries; also dewatered sewage solids, especially if they are mixed with ground refuse; and cans and bottles that have no salvage value can be economically ground with the remaining refuse. When large grinders are used (plants of more than 100

tons a day) even large, bulky objects may be handled. A municipal refuse composting plant can dispose of all these wastes.

3. Normally composting offers favorable conditions for salvage of rags, glass, cardboard, paper, cans, and metals.
4. A well located refuse composting plant may reduce the cost of hauling refuse to the point of disposal.
5. Flexibility of operation permits a 100 to 200 per cent overload in design capacity for several days by increasing the time the receiving bins and grinders operate.
6. Weather does not affect an enclosed composting plant, although heavy rain adversely affects most kinds of outdoor composting.

Disadvantages

1. Capital and operating costs apparently are relatively high.
2. Whether the end product can be marketed is not yet proven and seasonal use of the end product may require special marketing procedures or outdoor storage.
3. Trained personnel to operate composting plants are not readily available.
4. Refuse that damages grinders must be removed and disposed of separately—tires, pipes, heavy stones, mattresses, for instance.
5. If cans and bottles have no local salvage value they must either be removed and disposed of separately or ground with the organic matter, thus somewhat reducing the quality of the finished compost.
6. Site procurement for a composting plant is difficult because any type of refuse disposal facility is considered a nuisance in most neighborhoods.

Fundamentals of Composting

Modern composting is an aerobic, thermophilic, biochemical process that with the assistance of mechanical equipment and controls is faster and more effective than older, relatively slow, mesophilic and anaerobic processes. The stabilization of organic matter in a modern composting process is accomplished by bacteria and other microorganisms that use large volumes of oxygen and produce considerable quantities of heat.

Temperatures of 160° to 170° F., which can destroy disease producing organisms, are maintained relatively easily.

The following conditions have been found to be desirable for efficient aerobic composting:

1. Raw materials should have a carbon to nitrogen ratio of 50 to 1 or less. They should have no serious deficiency of essential food elements and should be within a normal pH range (5.5 to 8).
2. Material should be mixed and ground (fine grind for mechanical composting, medium to coarse grind for windrow or area composting).

3. Moisture should be controlled to 50 to 60 per cent throughout the process.
4. Air should be thoroughly dispersed throughout the composting material with an excess of oxygen remaining.
5. Seed compost should be recycled in the amount of about 1 to 10 per cent by weight.

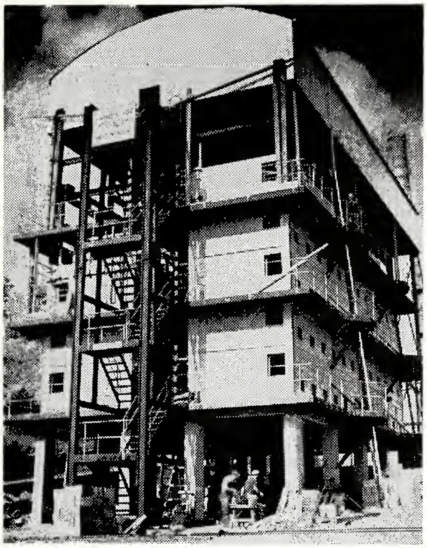


Fig. 117. A view of the tower of the composting plant at Jersey, Channel Islands, Great Britain. Aerobic fermentation takes a week in the tower, the refuse being dropped one floor a day from the six self-emptying floors; windrowing takes four to six weeks.

If high-rate composting is used, the following additional conditions have been found desirable:

1. Constant slow stirring or intermittent stirring every 5 to 10 minutes or a combination of forced air and less frequent stirring.
2. Temperatures should be controlled throughout the process.
3. The pH should be controlled to prevent nitrogen loss.
4. Digestion should be a continuous flow process in three or four stages, including recycling of seed and thorough mixing for each stage. The last stage may combine slower digestion with natural drying from the heat.

High-rate composting can be done in two to five days using selected materials but requires a properly engineered mechanical digester. Refuse can be composted without a digester but may take 10 to 15 days. It is not necessary to compost all organic matter—only the putrescible material that attracts rodents and insects or creates odors. The remaining resistant material can be broken down in the soil where its further decomposition stimulates soil bacteria and plant growth.

The major objectives in composting are:

1. To stabilize putrescible organic matter.
2. To kill all pathogens and weed seeds.

3. To conserve the nitrogen, phosphorus, potash, and resistant organic matter found in the raw material.
4. To produce a uniform, relatively dry end product, free from objectionable and harmful objects.
5. To conduct the process in a sanitary manner, free from insects, rodents, and odors, and as inexpensively and in as dependable a manner as possible.

Types of Biological Decomposition

There are two general types of biological decomposition: aerobic and anaerobic.

Aerobic (with oxygen) decomposition is efficient and rapid, resulting in the oxidation of organic matter primarily to minerals, humus, carbon dioxide, and water. The aerobic process, properly carried out, does not produce foul odors; it is the one employed in most modern scientific composting.

Anaerobic (without oxygen) decomposition is slower and less efficient, resulting in the reduction of organic matter primarily to minerals, humus, methane, and carbon dioxide. This process is similar to the digestion of sludge in sewage treatment, and if it is not properly controlled causes offensive odors by release of sulfides and mercaptans.

There are also two other general classifications of biological decomposition: thermophilic and mesophilic. Thermophilic (high-temperature) decomposition occurs at well above body temperatures and is the result of the action of "heat-loving" microorganisms—bacteria, actinomycetes, and fungi. The energy produced by aerobic composting is sufficient to heat the mass to the high temperatures shown in Table 31 if conditions are correct for it. Mesophilic (moderate-temperature) decomposition occurs widely in nature at lower temperatures. Heat is also liberated by aerobic or oxidative decomposition in the mesophilic range. The most rapid composting is accomplished by aerobic, thermophilic microorganisms.

TABLE 31

MINIMUM, OPTIMUM, AND MAXIMUM TEMPERATURE RANGES FOR THERMOPHILIC AND MESOPHILIC BACTERIA

Bacteria	*Minimum*	*Optimum*	*Maximum*
Thermophilic	25-45°C. 77-113°F.	50-55°C. 122-131°F.	85°C. 185°F.
Mesophilic	15-25°C. 59-77°F.	25-40°C. 77-104°F.	43°C. 109°F.

Raw Materials

The primary purpose of a municipal refuse composting plant is to treat solid wastes. Therefore, if refuse is collected together, provision must be made at the plant to dispose of components that cannot be composted, such as metals, tires, and glass. The great variety of refuse materials that has been composted indicates that the raw materials are not greatly restricted. For example, materials with carbon to nitrogen ratios (C/N) varying from 20 to 78 were successfully composted at the University of California. While it is desirable to keep the C/N range in raw materials from 30 to 40, it is not essential. Somewhat longer composting time is required with a high C/N than a low one. The desired end C/N is about 26 to 31. Mixed refuse (garbage and rubbish) composts better than separate garbage or rubbish. Garbage often is too wet; rubbish has too high a C/N. The optimum mixture for composting is a well blended mixture of refuse and partially dewatered raw sewage solids plus suitable organic industrial wastes.

A single type of industrial or agricultural waste may not be sufficiently balanced to compost well alone; if so, it may be necessary to add other wastes. If carbonaceous matter is required, sawdust, paper, or straw may be added. High nitrogenous wastes include fish scraps, fowl manures, and sewage sludge. It should be unnecessary, except in extreme cases, to buy supplemental materials.

Particle Size

Refuse as it is collected in a city is much too coarse and irregular for efficient composting and should be ground at least once, if not twice. Grinding accomplishes several things:

1. It vastly increases the surface area available for the microorganisms to attack.
2. It mixes the refuse into a more uniform mass.
3. It breaks down the cell structure, releases fluids, and in general makes the material more susceptible to decomposition.

Grinding does, however, reduce the permeability of the mass. The finer the grind the more difficult it is to aerate. How fine the material should be ground depends on what composting process is used. Fine grinding is recommended for mechanical composting with constant or intermittent stirring. A medium grind is recommended if forced air is used with either windrow or bin-type composting. Turning and shredding during the course of digestion further reduces the particle size. Low permeability may, under the right conditions, be overcome by positive air pressure from beneath. Coarse grinding is recommended for windrow or bin composting if forced air is not used and if natural ventilation or turning alone is used to aerate. Even with coarse grinding, natural diffusion of oxygen into windrows is far slower than the organisms demand it and the rate of decomposition is slowed.

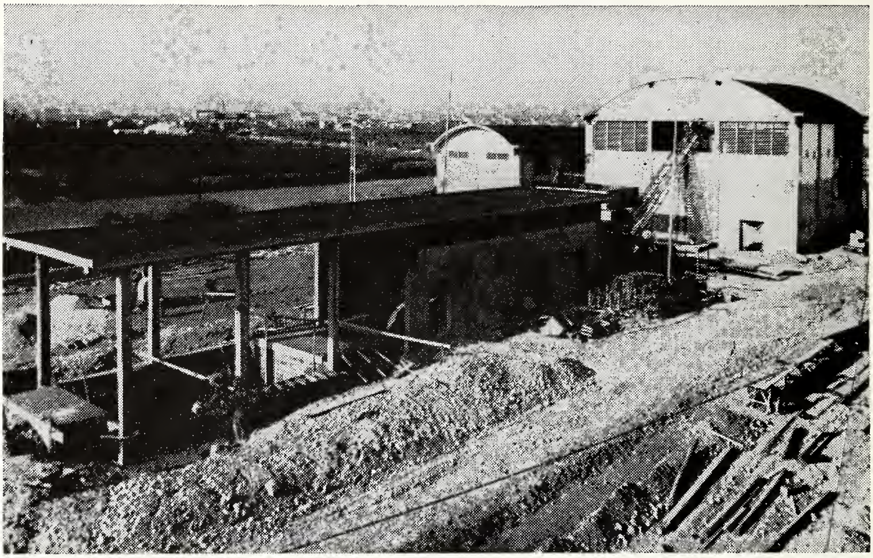


Fig. 118. Earp-Thomas composting plant in Verona, Italy, has a capacity of 50 tons a day.

Moisture and Liquid Contents

Experiments at the University of California indicate optimum moisture for aerobic composting of coarsely ground refuse in windrows or open bins, using aeration by turning and natural ventilation only, to be 40 to 60 per cent (moisture content computed on a wet basis by oven drying). Similar experiments with mechanical composters and continuous aeration of refuse at the United States Public Health Service laboratory at Savannah, Georgia, indicate 55 to 69 per cent moisture as optimum. Yet 60 per cent was found to be too wet for wet garbage at a plant in San Diego and for wrapped garbage at Michigan State University. Thus it has been determined that other factors also affect the optimum moisture content: (1) the rate of digestion is affected by the adequacy of the air supply by natural ventilation, which in turn is adversely affected by finely ground materials; (2) aeration is hindered by filling of voids with all liquids, not just water; (3) ash or mineral matter does not absorb water as well as organic matter; (4) lipids (fats and oils) are liquid at normal composting temperatures and are present in substantial quantities in garbage; (5) fine grinding releases more liquids than coarse grinding, further restricting air flow through the material. A formula for liquid content has been proposed that should be more representative of the materials composted and should narrow the ranges reported for liquid content by workers with different materials and techniques. On the basis of this formula the estimated "effective liquid contents" of raw materials used at Savannah and Michigan State University ranged from only 68 to 70 per cent. The formula (all values on a wet basis) is:

$$\text{Effective \% liquid} = \frac{100\ (\%\ \text{moisture} + \%\ \text{lipids})}{(100 - \%\ \text{ash})}$$

Mechanical digestion with continuous or intermittent mixing to assist in aeration can efficiently compost materials with a higher liquid content than windrow or bin composting employing forced air for aeration. Windrows relying on natural ventilation or periodic turning for aeration should have the lowest effective liquid content.

Low moisture retards or stops microbial action, but whereas some authorities have specified the lower limit for composting to be 40 per cent moisture, activity in composting has been observed in a windrow (temperature over 154° F.) at a moisture content as low as 24.5 per cent. For compost that is to be shipped in unlined bags, it is desirable to reduce moisture to about 10 per cent. If polyethylene lined bags are used, moisture content can be 20 per cent without causing deterioration. At these low moisture contents nearly all bacterial action is arrested, thus cutting down on odors and the dangers of heating, spontaneous combustion, and rotting bags.

Aeration

Aerobic organisms require oxygen just as they require moisture and food. In composting, oxygen is usually supplied by atmospheric air, by forced aeration with a blower or fan, by stirring, or by a combination of forced air and stirring. Natural aeration is dependent primarily upon convection and diffusion and is undependable and less efficient. In theory, the carbohydrates are decomposed by oxidation in accordance with the following hypothetical formula:

$$2C_{13}H_{20}O_7 + 29O_2 \rightarrow 26CO_2 + 20H_2O + \text{heat}$$

There are many intermediate steps and the formula given above includes only lost volatile solids and excludes all elements except carbon, hydrogen, and oxygen. However, it indicates a need for considerable oxygen from an outside source and also the production of appreciable amounts of carbon dioxide, water, and heat. In mechanical units with continuous aeration, the amount of air found to be desirable was 10 to 30 cubic feet per day per pound of volatile solids (in the initial charge). This provided more than twice the amount of oxygen needed for the oxidation of the organic matter but was desirable because lower rates resulted in prolonged composting and higher rates resulted in rapid cooling and drying of the refuse. The maximum rate of oxygen utilization measured at Michigan State University was 0.0244 parts of oxygen a minute per 100 parts of dry weight. On the basis of 50 per cent of the oxygen remaining in the air that was used, 37 cubic feet of air per day per pound of total dry solids, or about 44 cubic feet of air per day per pound of volatile solids, would be required.

Windrow composting also requires oxygen but the amount required or used is difficult to measure. However, use of an oxygen analyzer with sampling probe can measure the oxygen present at various depths within a windrow, pile, or bin. Normal atmospheric air contains about 21 per cent oxygen by volume; thus, a value of 3 per cent oxygen indicates that approximately one-seventh of the oxygen in normal air is present in the atmosphere within the compost windrow. The studies made in Chandler, Arizona, by the United States Public Health Service in which this technique for oxygen determination was used, show that for coarse grind, low moisture, natural ventilation conditions and at the one-foot depth, oxygen was lowest about one day after turning but recovered to 5 to 7 per cent. However, at the two-foot depth the oxygen value was consistently below 2 per cent and usually below 0.9 per cent. It was determined that regrinding usually restored oxygen to values of 14 to 19 per cent for the first 30 minutes or so; values as low as 1.2 to 2.7 per cent were reached in from 3 to 5 hours after regrinding. This gives an indication of the rapidity of the bacterial action and shows why mechanical composting with positive aeration or use of forced air may be more rapid than other methods.

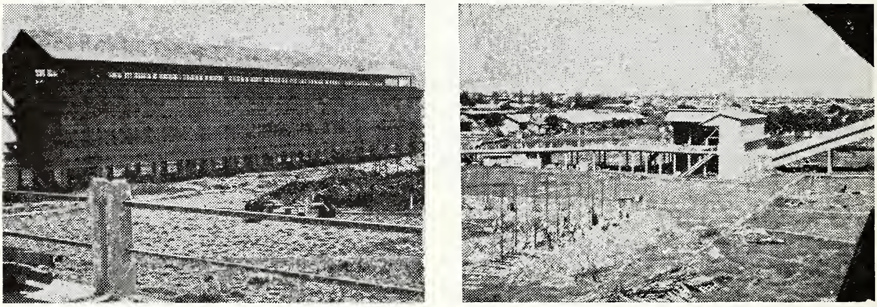


Fig. 119. Left, composting plant in Bangkok, Thailand (330-ton-a-day capacity), in which refuse is composted one day on each of the six floors and is cured for 30 days in a warehouse; right, receiving bins.

There is a definite relationship between oxygen used, carbon dioxide produced, and water produced and evaporated in aerobic composting; and all three are related to the temperature of the compost. As the temperature increases, so do the other three values—up to a point. The ratio of volume of CO_2 to volume of O_2, called the respiratory quotient, has varied from about 0.85 to 0.95 in the Savannah composting runs.

Temperature

Experiments indicate that the initial or acid stages of decomposition where simple carbohydrates such as sugars and starches break down has an optimum temperature of about 95° F. Artificial heating of the compost above this temperature is inhibitive to rapid digestion. This stage may last from a half to one day in high-rate mechanical composting. With slower windrow decomposition, digestion may last from two to seven days, depending on the degree of control of oxygen, moisture, and temperature.

It is apparent that optimum temperatures for the middle and latter stages of decomposition where protein and other nitrogenous materials break down are about 140° to 150° F. It is only after temperatures go down and the active composting process is complete that actinomycetes and fungi increase in numbers and play an active role in breaking down the more complex carbohydrates such as cellulose.

Some have advocated heating to speed up the initial phases of composting, although tests in Savannah and at Michigan State University indicate this may be detrimental.

Temperatures should be sufficiently high for a long enough time to accomplish three objectives: (1) kill pathogenic organisms, (2) destroy weed and vegetable seeds, and (3) destroy fly eggs and larvae. Most weed seeds and fly eggs and larvae are killed at around 120° F. in a few days and under moist conditions, but 140° F. has been recommended to be safe. Prolonged high temperatures of 158° to 167° F. may inhibit some of the beneficial microbial action and increase nitrogen loss due to vaporization of ammonia. The latter occurs mainly at the most alkaline reactions (pH 8.5 to 9) and at the lower C/N values (30 or less).

There should be little difficulty in maintaining a temperature of 140° F. in all of the composting mass for several hours—even days—in a mechanical unit. But in windrows the outer portions (and if there is no forced air, the bottom and center portions) are usually cooler than the inner portions—the bulk of the material. To be reasonably certain that a maximum portion of the material is subjected to pasteurizing temperatures, several mixings may be necessary. Pasteurizing of the entire mass is aided by using a one- to two-inch covering blanket of finished compost to hold the heat in the pile. One or two temperature cycles of 140° F. or more may not be sufficient to kill all pathogens if the material is not completely turned under during the process or if it is not properly insulated.

Acidity and Alkalinity

The relative intensity of the acidity or alkalinity of a material as measured by pH is a quick and convenient—although indirect—yardstick for measuring digestion. Because pH is an indirect yardstick, it is reliable for any material only after its change pattern has been established for the particular material and the digestion process employed. Raw refuse or raw garbage generally has a pH value of 6 to 7, approaching neutrality (7) when it is fresh, and slight acidity (5 to 6) when it is a day or so old. Ashes in refuse may cause a higher initial pH. Some decomposition starts in the refuse or garbage while it is in the home storage container. Initial aerobic decomposition results in a drop of pH to a range of 4.5 to 5.5 as the acid phase occurs. The pH generally rises after one to four days and is usually followed closely by a rise in temperatures into the thermophilic range. By the time the peak

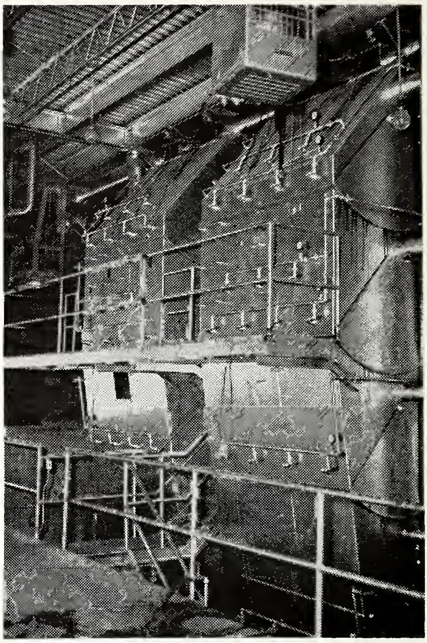


Fig. 120. The Sanitary Compost Corporation Plant in Williamston, Michigan, has a five-ton-a-day capacity; digestion takes 21 to 28 days.

temperature is reached the reaction generally is alkaline (pH 8 to 9). Then the longer the composting process is continued (the rate is much reduced), the nearer the reaction approaches a pH of 7.

It is possible to adjust initial acid conditions with lime but little or no real advantage is to be gained by doing so. Lowering of final pH by the addition of sulfur dust can lessen to some degree the loss of ammonia but the advisability of this practice is also questionable without further study.

Microorganisms

Such wastes as rubbish, garbage, sewage sludge, manure, and mixed vegetable wastes normally contain many types of bacteria, actinomycetes, and fungi. Research indicates that no pure culture of organisms can compare with a mixed culture in the aerobic composting of manures and other organic matter. Many types are believed necessary for composting, and the required microorganisms rapidly multiply if there is the proper environment for them. Temperature, moisture, aeration, pH, and type of food supply must be within a suitable range to provide the best environment for growth. Studies indicate that special "starters" or "inoculants" are unnecessary—if conditions are not right, added organisms will not grow and multiply; if they are right, the organisms already present will grow and multiply. Experience shows, however, that recycling of relatively small amounts of seed (1 to 10 per cent) of actively composting material appreciably shortens lag periods required for large numbers of the right organisms to develop for each stage.

Some materials are difficult to decompose aerobically and require considerable time. Lignins and cellulose are resistant materials and are usually only attacked after the more readily decomposable materials have been used up (sugars, starches, lipids, proteins). Cellulose in the form of paper is a highly resistant material. The actinomycetes and fungi will completely decompose the paper content of refuse in time, however. Complete decomposition of resistant materials such as lignins and cellulose is not necessarily desirable because they are of value to the soil and plant life.

The many microorganisms involved in composting and the role of each are complex, but an extensive knowledge of their characteristics is not necessary for a compost plant operator.

TABLE 32

SUMMARY OF ANALYSES AND WEIGHT CHANGES IN LABORATORY COMPOSTING OF REFUSE AT SAVANNAH, GEORGIA, 1958

(Average values based on 13 runs with 32 composting units; batch time averaged 8.8 days)

Constituent	*Per Cent of Dry Wt.*		*Signif. Diff.* ([X] *at 95%)*	*Weight (lbs.)*		*Signif. Diff.* ([X] *at 95%)*	*Per Cent Change in Weight*
	*Raw Refuse**	*Compost*		*Initial*	*Final*		
Total wet wt.	100.0[Y]	100.0[Y]		40.47	27.31	Yes(−)	−32.5
Moisture	57.1[Y]	56.8[Y]	No	24.58	15.85	Yes(−)	−35.5
Total solids (dry wt.)	100.0	100.0		15.89	11.46	Yes(−)	−27.9
Ash (dry wt.-volatile solids)	7.8	12.4	Yes(+)	1.25	1.43	Yes(+)	+14.4
Volatile solids	92.2	87.6	Yes(−)	14.64	10.03	Yes(−)	−31.5
1. Lipids (ether soluble material)	10.1	3.3	Yes(−)	1.62	0.38	Yes(−)	−76.7
2. Crude fiber	35.9	45.8	Yes(+)	5.66	5.26	Yes(−)	− 7.0
3. Total sugar	4.9	0.0077[Z]	Yes(−)	0.80	0.0008	Yes(−)	−99.9
4. Starch	8.1	1.4	Yes(−)	1.32	0.15	Yes(−)	−88.4
5. Protein (6.25N)	8.2	11.0	Yes(+)	1.29	1.26	No	− 2.7
6. Sum: (1)-(5)	67.2	61.5	Yes(−)	10.69	7.05	Yes(−)	−34.1
7. Volatile solids−(6) (undetermined)	25.0	26.1	No	3.95	2.98	Yes(−)	−24.6
Nitrogen (N)	1.30	1.76	Yes(+)	0.207	0.202	No	− 2.7
Carbon (C)	50.0	47.7	Yes(−)	7.96	5.47	Yes(−)	−31.3
Ratio: C/N	38	27	Yes(−)	38	27	Yes(−)	

*As composted, after sorting and grinding.

[X]—Significant difference at 95 per cent level (t-test); — indicates decrease; + indicates increase.

[Y]—Per cent of wet (total) weight.

[Z]—Only one value (0.2%) was above minimum limit of analysis.

Changes During Composting

Changes in refuse material that may occur during the mechanical composting process are given in Table 32.

In the Savannah research work it was found that sugars usually disappeared by the third day and 75 per cent or more of the starches and lipids were decomposed by the end of the run (average duration was 8.8 days). Total Kjeldahl nitrogen (excludes nitrite and nitrate-nitrogen, believed to be relatively low) increased percentagewise but showed no significant change on a total weight basis. Carbon was drastically reduced, whereas there was only a 7 per cent loss in weight of crude fiber—probably mostly paper. Of the 25 per cent undetermined portion in the raw material and the 26 per cent in the final compost, the weight reduction of these materials was also significant—about equal to the over-all weight reduction or loss. As a whole, the dry weights and volatile solids were decreased an average of 27.9 per cent and 31.5 per cent respectively. The relation of total bacterial count to composting activity as indicated by the index of oxygen uptake in the Michigan State University experiments are given in Figure 121.

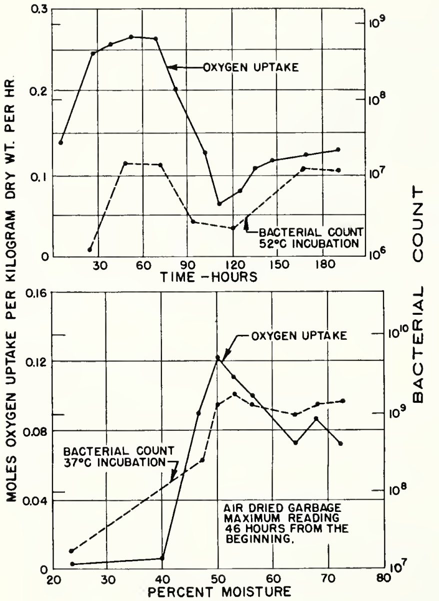


Fig. 121. Typical relationships obtained between oxygen uptake and bacterial count in laboratory digesters at Michigan State University.

Concentration of Volatile Acids

In the aerobic composting process, as in the anaerobic digestion process, the excess concentration of volatile acids can be a serious problem, causing severe inhibition or complete breakdown of the process. In the anaerobic digestion of sewage sludge a slowdown occurs at about 3,000 parts per million (0.2 per cent) volatile acids and a complete stoppage occurs before a concentration of 5,000 ppm (0.5 per cent) is reached. Fortunately, the composting process appears to be much less sensitive to volatile acids, and concentrations of 10,000 ppm (1 per cent) do not seem to cause any serious inhibition.

It might also be assumed that composting is probably incomplete as long as a volatile acid concentration of 4,000 to 5,000 ppm persists.

Public Health Aspects

Pathogenic organisms and their destruction have already been mentioned. Aerobic composting, with continuous or frequent mixing, should render the final compost free of all pathogens as a result of thermal kill alone. Aside from time-temperature, there is probably a biological antagonism (antibiosis) that may render the composting matter free of pathogens at considerably lower temperatures than required for pasteurization. This should not be relied on until more proof is offered, and thermal kill at 140° F. for one hour or more should be used. However, there has not yet been a conclusive study of the survival of pathogenic organisms under normal composting conditions, either in the windrow or enclosed processes.

Control of disease vectors, primarily rats and flies, is an important public health problem in waste disposal. The raw materials for composting usually attract flies and rodents and may offer excellent breeding places if not properly handled. In fact, the raw materials are likely to be infested with fly larvae when they reach the composting plant. Prompt handling of the wastes and plant cleanliness are required, therefore.

Pregrinding offers immediate control and is a preventive step in fly control. While the grinder may destroy some flies in the raw material, it also immediately aerates the mass and practically eliminates odors, even in septic sludge and decomposing garbage. Fly and rat breeding are controlled in mechanical composters. If the best conditions for composting are provided, there should be little trouble with flies and rodents in windrow composting, although several turnings within seven days are necessary to prevent propagation of flies in cool parts of the windrow. Moisture is particularly important. Both too much and too little should be avoided: flies like wet material for egg-laying and development of larvae, and larvae need relatively dry material for pupation. If a pile or windrow is relatively wet (more than 60 per cent moisture) and is undisturbed for some days so that the outer portion dries to a depth of six or more inches, larvae may migrate from the moist interior to the dryer exterior and flies may hatch.

Windrow composting may be done on a hard, impervious surface, such as a concrete slab or asphalt pavement, which offer no soil or sand for the larvae to migrate to for pupation. A slab is also clean and prevents the compost from becoming excessively contaminated with soil. Soil contamination reduces the value of the compost and interferes with sampling and analytical projects. Chemical control of insects and rodents should be used, if required, in addition to—but not in place of—good operating and housekeeping procedures.

Practical Methods of Composting

There are a number of proprietary composting methods that have been promoted as being the "best" answer to the organic waste disposal problems of municipalities. Although each has merits, none has yet been offered that meets all of the objectives outlined in the previous section, although some meet most of them. The important point is that except for complete conservation of nitrogen, these objectives can be fulfilled by combining the knowledge and experience gained by the various groups that have worked with composting.

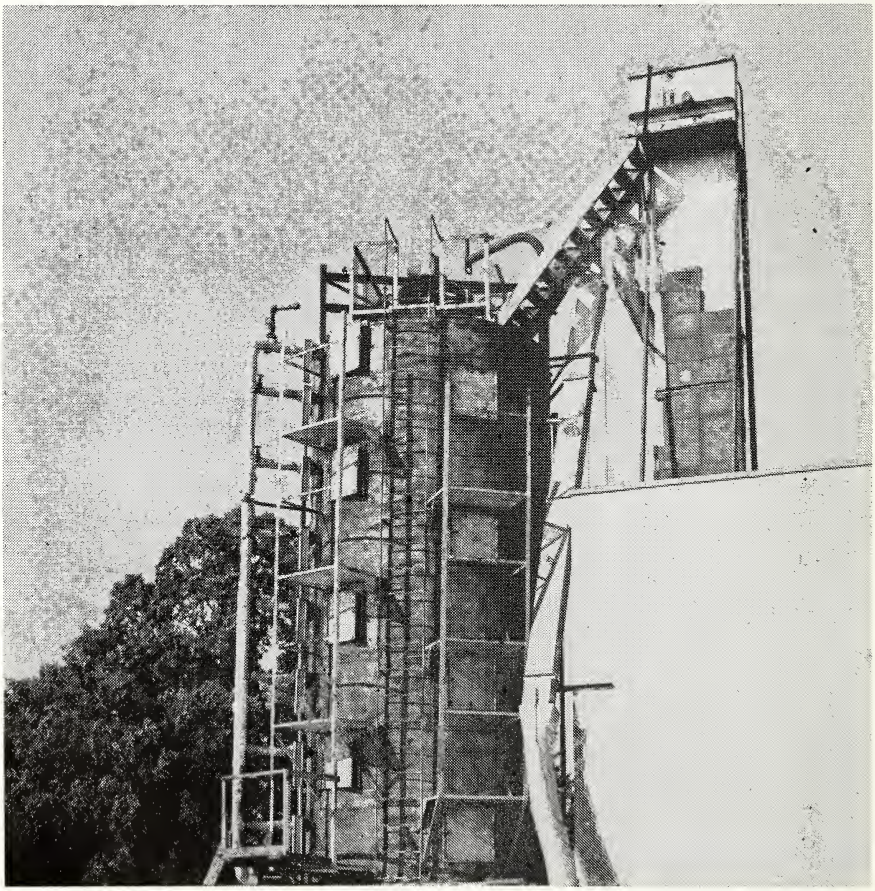


Fig. 122. Modified Earp-Thomas digester used in composting studies at Michigan State University from 1952 to 1955; capacity is five tons a day.

Although there are a number of ways to compost refuse, two appear to be more efficient and economical under usual conditions in the United States. These are the mechanical digestion and the modified windrow or area composting methods.

Mechanical Methods

A number of proprietary mechanical digesters have been developed in recent years. Four are classed as continuous-flow-through-type. Three of these, the Dano, the T. A. Crane, and the Hardy digesters, are horizontal units, and the other, the Earp-Thomas digester, is a vertical unit.

The Dano digester, used to some extent in Europe, was described previously. A 50- to 80-ton modified Dano plant is in operation in Sacramento, California.

The T. A. Crane digester is a three-deck horizontal unit with separate agitating and aeration mechanisms for each level. Provision is made for reseeding on each deck and increased aeration by forced air and blowers. The Earp-Thomas digester is an eight-deck vertical cylinder. Material is agitated and aerated by plows on arms that are turned from a central vertical shaft. A modified 5-ton-a-day model using forced air was used for two years at Michigan State University for research. By early 1960 no full-scale digester—either the Crane or Earp-Thomas design—had been installed for municipal use in the United States, although a modified Crane digester is operating in Kobe, Japan, and Earp-Thomas digesters in Italy and Switzerland.

The Naturizer digester at Norman, Oklahoma, although a continuous-flow unit, biologically is essentially of the batch-type. It is a six-deck structure with intermittent grinding between the third and fourth decks. Movement in the digester is produced by a slowly moving wooden

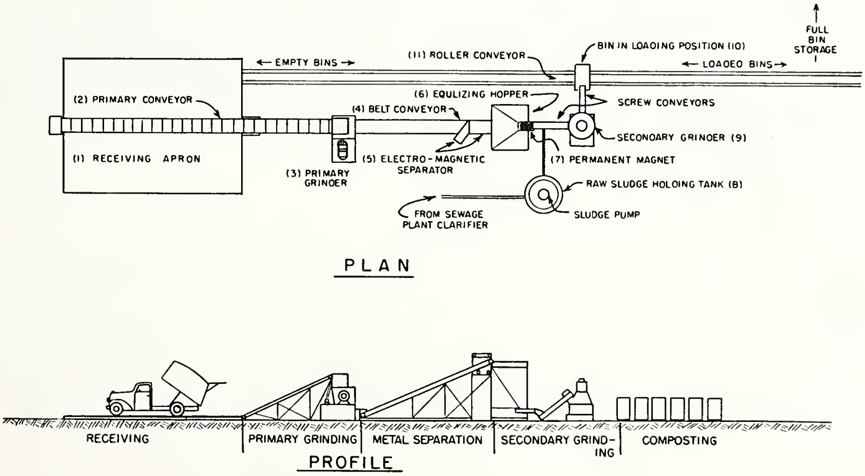

FULL BIN STORAGE
BIN IN LOADING POSITION (10)
(11) ROLLER CONVEYOR
← EMPTY BINS →
← LOADED BINS →
(2) PRIMARY CONVEYOR
(6) EQULIZING HOPPER
(4) BELT CONVEYOR
SCREW CONVEYORS
SECONDARY GRINDER (9)
(1) RECEIVING APRON
(3) PRIMARY GRINDER
(5) ELECTRO-MAGNETIC SEPARATOR
(7) PERMANENT MAGNET
RAW SLUDGE HOLDING TANK (8)
FROM SEWAGE PLANT CLARIFIER
SLUDGE PUMP
PLAN
RECEIVING
PRIMARY GRINDING
METAL SEPARATION
SECONDARY GRINDING
COMPOSTING
PROFILE

Fig. 123. Schematic layout of demonstration compost plant at Chandler, Arizona, operated by United States Public Health Service.

pan-conveyer and forced air keeps the material aerobic. The shallow pan-conveyer, or receiving hopper, accommodates two trucks at once. A weighted sluice has been designed to control the flow onto a picking belt. The primary grinder consists of a rotating cylinder about 6 feet in diameter and 30 feet long, with several hundred curved swinging saw-toothed hammers, which break up the refuse when they hit it. The secondary grinder is essentially a conventional swing hammer mill. After processing for about three days and dropping several levels, the material is reground and digested another three days in a second three-level digester, followed by the final grinding.

In the late 1950's, a two-ton-per-day plant that composts a mixture of dewatered raw sewage solids, ground municipal garbage, and ground corn cobs was constructed at Williamston, Michigan. Digesters of a special design, with four decks each, are used. Although provision is made to blow air into each deck, difficulty is reported in keeping the material aerobic because the only agitation it receives is when it is dropped from one deck to the next.

Modified Windrowing or Area Methods

The process of sorting and shredding refuse and placing it in rows five or six feet deep for composting is commonly termed "windrowing." Windrowing, employing preseeding, forced air, and periodic turning and shredding, and often referred to as "modified windrowing," is much more efficient and requires about half the time of ordinary windrowing, which depends on natural ventilation and occasional turning for aeration. In modified windrowing, material may be piled in long windrows about 4 to 6 feet high and 8 to 12 feet wide. Controlled amounts of air may be blown up through the material in a number of ways.

The term "area composting" is often used interchangeably with "modified windrowing," but they should be distinguished from each other. Area composting requires a third of the space required for windrow composting for the same size plant. In "area composting" ground material is piled to a uniform depth in large, well defined areas. Controlled amounts of air are distributed through ducts under each area and pass up through porous, sandy soil or, preferably, through an especially designed porous floor. Seeding and turning may be employed; when both are used, the process reportedly takes only 10 to 14 days.

Self-propelled machines have been developed that will pick up, shred, and lay down all the material several times during the process. One of these machines was used on refuse that had not been ground before. Doing so greatly reduces the normal capacity of the machine, however. The same thing can be done but less efficiently with a front-end loader and a larger shredder or with some commercial self-propelled loaders.

Capital and Operating Costs

Since there are so few composting plants in operation in the United States that handle refuse for municipalities, capital and operating costs can only be estimated on the basis of experience in pilot operations. There is good reason to believe, however, that costs will approximate those of an incineration plant for a comparable amount of refuse disposal and that net costs will vary widely with the type of plant, degree of mechanization, and amount of revenue there is from the sale of the end product. Capital costs may be as low as $1,500 per ton of daily capacity and as high as $6,000; and plant operating costs may vary from $2 to $5 a ton of refuse received at the plant. Revenue from the sale of the end product can either reduce the costs or can produce a profit under favorable conditions.

Experience Outside United States

There are a number of refuse composting plants abroad, several of which were designed and built after considerable study and experimentation.

In Edinburgh, Scotland, separation-composting is done by the Dano process. Refuse is dumped into two 40-ton oscillating bottom hoppers, which in turn dump the refuse on a conveyer belt where it passes over two vibrating perforated steel screens. There ashes, dust, stone, and glass fall into storage hoppers and are carried to a dump. Refuse that does not go through the perforations of the screen is carried forward on rubber conveyer belts, ferrous metal and tin cans are removed by magnetic pulleys, and other salvageable material is taken off by hand. The remaining refuse drops off the end of the belt and without being ground goes into two Dano biostabilizers, which are horizontally rotating cylinders 80 feet long and 11½ feet in diameter. Sewage sludge is added to increase moisture and air is blown into the mass during the digestion period. During the five days of digestion, temperatures range

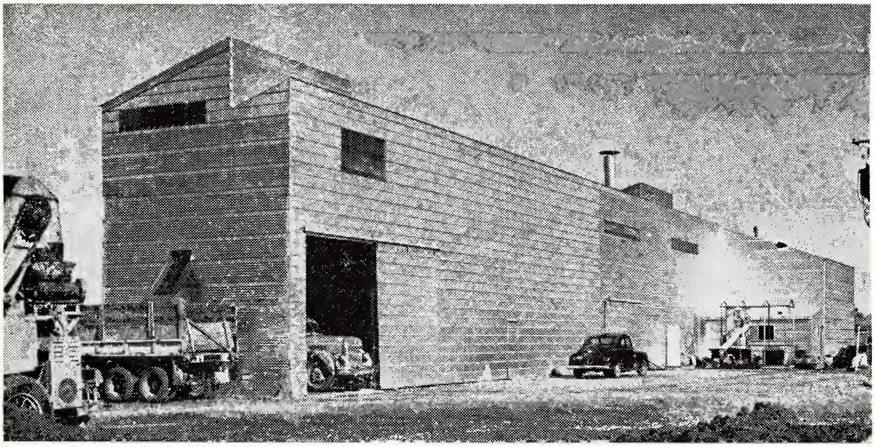


Fig. 124. Fifty-ton-a-day compost plant at Sacramento, California.

between 120° and 130° F.; the material is reduced in size because the rotation causes friction on the material. After passing through the barrel stabilizers, the material passes through a rotary screen and the fine finish compost is conveyed to a storage bay either for immediate sale or for further maturing. Rejects from the screen are taken to a nearby dump; tin cans and rags are baled and sold for salvage; cullet is stored and sold to a nearby glass works.

At the separation and composting plant at Jersey, Channel Islands, Great Britain, refuse collected in the city is brought to the plant and dumped into a receiving hopper where it is removed by a steel pan-conveyer that carries it to a rotating screen. Material retained on the screen passes over a picking belt, across a magnetic separator, and through a rasping machine. Cinders from the rotating screen and rejects from the picking belt are taken to the dump. Fine dust is stored and remixed with the organic matter after grinding; slaughterhouse wastes and organic farm wastes are ground in a hammer mill and added at the same time; and sludge from a nearby sewage treatment plant is also added.

After thorough mixing the material is elevated by a large clam bucket to the top of a six-deck fermenting cell. Each deck of this specially designed Jersey digester is arranged to discharge the contents to the deck below. Ground material remains in each cell for one day so that retention in the tower is for one week. Afterwards it is matured in sheds for 60 to 70 days or more. The compost is sold to farmers and reportedly is in constant demand. Salvageable material is baled and sold.

In Kobe, Japan, there is a continuous-flow, three-stage horizontal mechanical digester plant in which composting is followed by two days of curing with forced air. The prototype 20-ton a day plant, constructed in late 1956, is adjacent to an old incinerator and night soil transfer station. Domestic refuse is put on a device that feeds it in uniform amounts onto a picking belt. After passing through a vertical swing hammer grinder, the refuse is conveyed to a mixer where about two-thirds of the refuse, by weight, is mixed with about one-third night soil containing 94 per cent moisture. The digester is similar in principle to the T. A. Crane digester. Material is kept aerobic by forced air and continuous slow stirring. After 48 hours in the digester, it is cured and dried for 48 hours in a porous bottom curing bin in which forced air is used. Rags and metal are salvaged. The end product reportedly is much in demand; it is sold at cost (about $2.20 a ton).

Plant Design and Operation

Experience with composting plants in the United States in which refuse is handled is limited to a few pilot and full-scale projects, but from those and on the basis of experience in Europe and the Far East it is possible to generalize on design and operational factors.

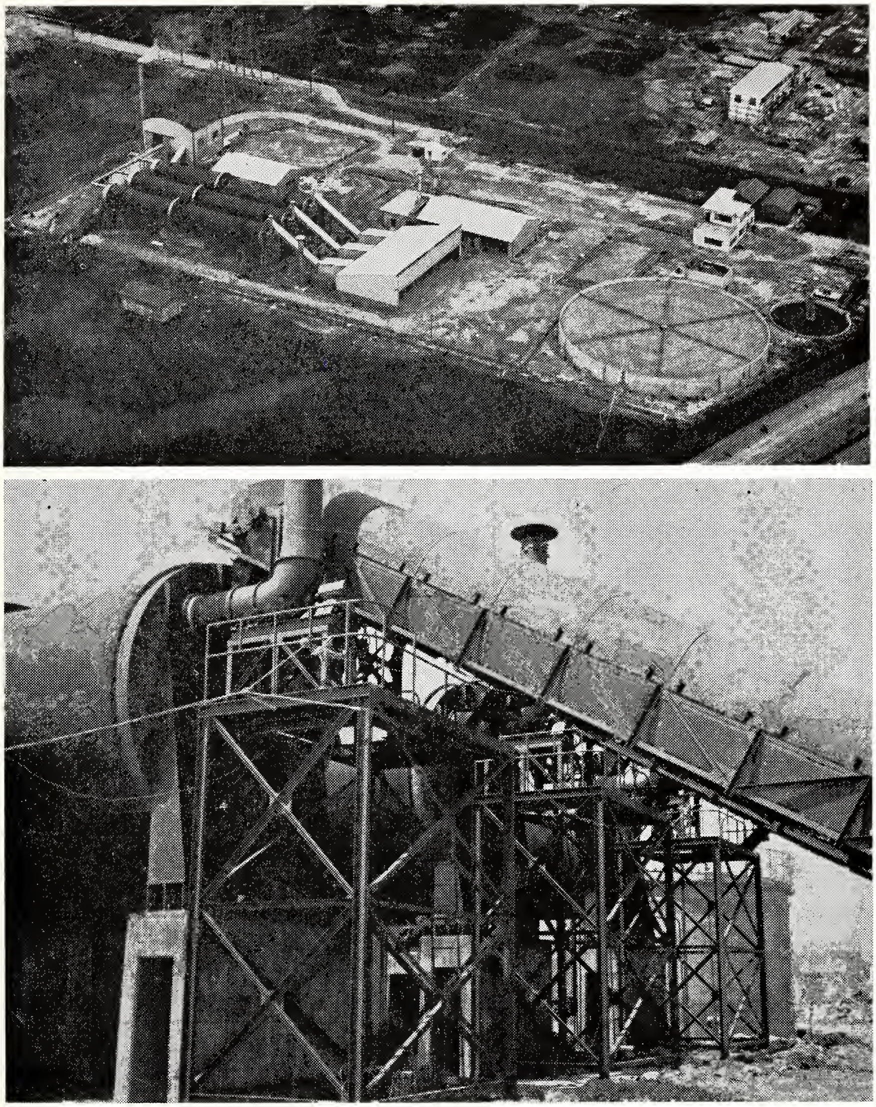


Fig. 125. In the Amagasaki, Japan, plant (top), refuse is in digesters for two and one-half days, followed by one to two weeks of windrowing; belt conveyer and inlet of digester are shown below.

Site Selection

Most new composting plants are fully enclosed, but regardless of whether a plant is open or enclosed considerable care must be given to selection of the site. A 400-ton-a-day area digestion type plant using forced air requires about five acres (including a rail or truck loading area and some open space around it). A fully mechanical 400-ton-a-day plant requires about two acres exclusive of storage and maneuvering space for vehicles. An unenclosed windrow plant of 400-ton-a-day capacity requires 10 to 20 acres or more, depending on the design of the plant.

Materials Handling

There is much to be learned about how to handle raw unground refuse from cities. Probably the best way is to use "live bottom" or vibrating storage bins into which the collection trucks can dump the refuse. Either a sugar cane type pan-conveyer or an oscillating pan may be used for the base of the storage bin. There should be a carefully designed device at the end of the storage bin that feeds the raw refuse evenly onto a picking belt and from there to a grinder. The major problems in the design and operation of these facilities are that the refuse arches, sticks, and goes onto the belt unevenly. Once the refuse has been ground it can be conveyed rapidly by belts or drags. Bucket conveyers should be used with caution with wet material because they have a tendency to stick and clog.

Grinding

Experience in grinding dry or moist refuse for composting is limited. Wet grinding into sewers or sewage treatment plants is better understood and perhaps more efficient but cannot be used in composting because it makes the refuse too moist. Grinding a small amount of refuse is more of a problem than grinding large quantities—several hundred tons a day. Extremely large and rugged grinders are available for big plants. They can grind 100-pound stones and 8-foot logs that are 6 inches in diameter, for instance. They are usually of the horizontal hammer mill type, are built with extra large throat openings and special throat feeding devices, and can grind 30 to 50 tons of refuse an hour. For mixed refuse in typical United States cities the most efficient shredding is believed to be done in two stages: through a primary, or coarse, grind followed by a secondary, or finer, grind. In small plants dual lines of equipment and primary and secondary grinding may not be economical. If the right grinder is used and most large objects are removed, single-stage grinding is efficient. Also the answer may come through the development of a two-stage vertical swing hammer grinder. Grinder wear and replacement or build-up of hammers represent an important part of the cost of composting.

Picking Belts and Salvage Separators

Picking belts, which should be just ahead of the grinder, are an essential part of a composting plant. They facilitate removal of objects harmful to grinders, such as rubber tires, mattresses, large stones, and metal, and they facilitate salvage operations. For example, cotton and wool rags and metal can easily be removed from a picking belt at this point. Tin cans can be removed with a magnetic separator when the refuse is between the primary and secondary grinders. Automatic shredders and bailers are available to salvage paper and cardboard.

Stirring, Aerating

Stirring is necessary only in certain mechanical digesters, but when it is, it is important that it be thorough because composting refuse has a tendency to stick to the sides and bottom of the digester. Aeration by forced air is highly recommended, whether mechanical digesters or modified windrowing, bin, or area composting are the methods used. Air pressure of two to six inches of water should be adequate in most instances but head losses should be properly computed to give even distribution. Maximum oxygen requirements, measured in the laboratory at Michigan State University, are 0.0244 grams of oxygen per minute per 100 grams of dry-weight material. If even 50 per cent of the air that is furnished is used it is equivalent to 37 cubic feet of air per pound of dry material per day. This rate of oxygen utilization is slightly in excess of that used in a well run activated sludge sewage treatment plant.

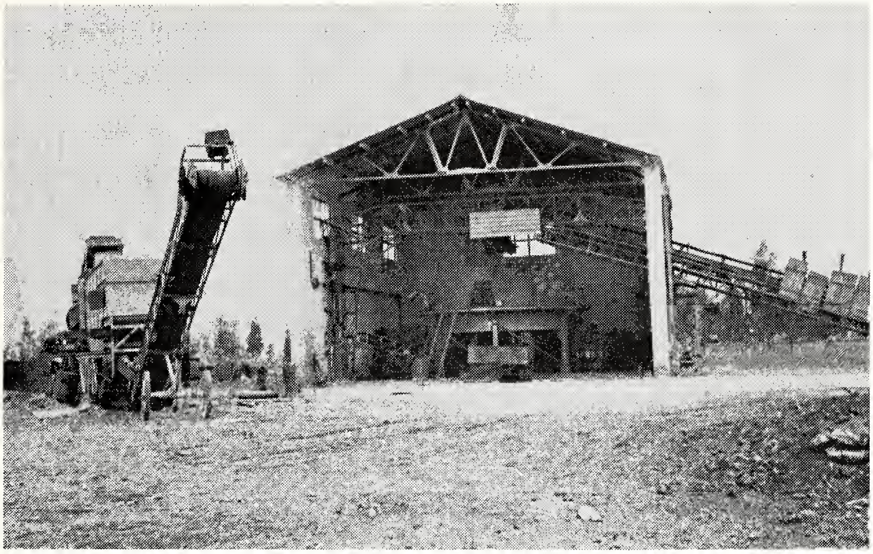


Fig. 126. Dorr Oliver composting plant in Tel Aviv, Israel.

Seeding and Reseeding

For mechanical digestion seeding by recycling of actively composting material is readily done and is essential for efficiency. For best results, reseeding should be done at the beginning of each stage of digestion. For modified windrow or bin composting a single seeding or recycling of seed material at the beginning is adequate. A safe approach for a large plant is to manufacture seed material with mechanical digestion units, because they assure a high quality seed material.

Temperature Controls

The most practical way to control temperature in mechanical plants is through the control of the volume of the air used for aeration. Volume can be automatically controlled by thermostats or it can be done manually. In windrow composting it is done by turning the compost material. Composting is most efficient when the optimum temperature is maintained for each stage of digestion. The aeration system and the controls for the various parts of the plant should be taken into consideration when the plant is designed.

Control of pH and Conservation of Nitrogen

Control of pH is unnecessary for most municipal wastes. Normal digestion follows from an acid pH of 5 to a final alkaline pH of 8 to 9. When composting material is high in nitrogen, it is possible that some nitrogen may be lost in the form of ammonia if the pH is allowed to rise too high. The possibility of acidifying the compost by the addition of powdered sulfur has been successful on a small scale. Although there is yet much to be learned about the conservation of nitrogen in the composting process, nitrogen losses are lessened by lowering the temperature and adding oxygen or blowing the exhaust gas through other composting materials while they are still in the acid stage of digestion.

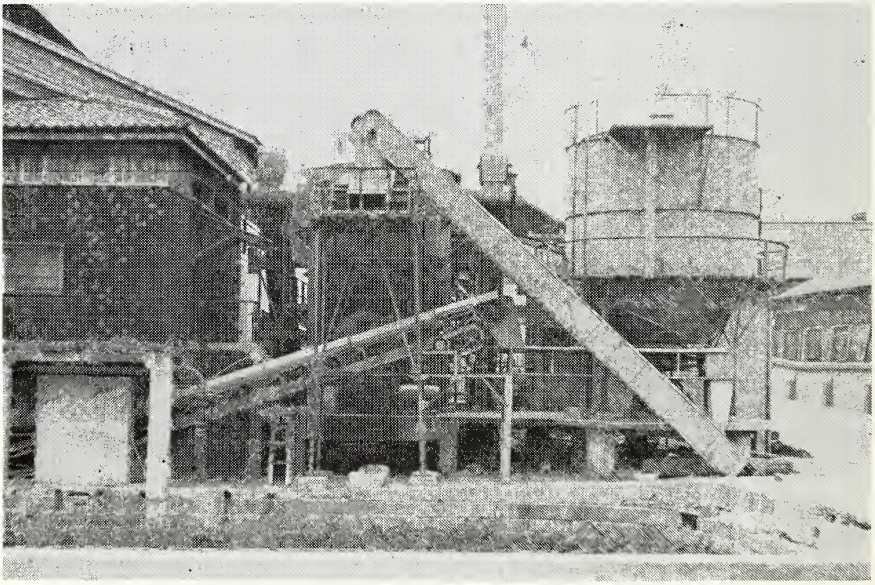


Fig. 127. A modified T. A. Crane digester, with 25-ton-a-day capacity, in Kobe, Japan, was built next to an incinerator.

Moisture Control and Final Drying

Since each type of refuse material has an optimum moisture content for rapid composting, it is well to control the moisture by adding wet or dry material during the process. The first obvious time is when the refuse is being ground or just afterward. If mechanical digesters are used, moisture is easily controlled throughout the digester and the wet material is stirred in evenly. With windrows, moisture may be added by special devices as the material is being turned. Wetting the top of the pile or injecting moisture into the pile is rather unsatisfactory, although it is probably better than not adding moisture at all. Toward the end of the composting process it is desirable to reduce the moisture content slowly and dry it as much as possible, using the heat produced in the final stages of composting to do it. The drying can be done reasonably well by blowing excess air through the material. A rather large amount of water is produced biologically through the composting process itself and it, as well as the original and added moisture, must be evaporated. One of the problems of composting out of doors is that during heavy rains it is impossible to prevent the piles from becoming too wet. Probably the best solution is to turn the pile as soon as possible after a heavy rain, thus distributing the moisture throughout the pile, which in turn aids in the loss of additional moisture through evaporation, especially during the turning process.

Measuring Degree and Rate of Composting

Those long associated with composting have depended upon appearance, odor, and feel of the end product to determine whether it has been properly composted. More scientific yardsticks are essential. It is not desirable to carry the digestion process too far because less organic material will then be available for enrichment of the soil. However, it is desirable to stabilize the material to the extent that upon being remoistened and piled it will not overheat, lose appreciable nitrogen, become offensive, or create sanitation problems. The exact point during the digestion process at which all of these criteria are fulfilled is difficult to determine for routine work. Because of the wide variation in the nature of materials composted, it is possible that no single criteria or yardstick can be used for all organic wastes.

For example, the change of pH during the normal course of digestion of garbage or animal manure from about pH 5 or 6 to 8 or 9 has proven to be useful. Other wastes with a high initial pH—about 8—may change little so that pH may be of little use as a measure unless its pattern has been predetermined. Currently used yardsticks for measuring the degree of composting are given in Table 33.

Oxygen consumed, ash (100 per cent of total organic solids), and especially total organic solids less crude fiber, are considered the best yardsticks to measure degree of digestion, although pH and transmittance are good, quick, indirect methods after their change pattern has been predetermined for the material and digestion process used. Chemical

TABLE 33

RELIABILITY OF TESTS TO DETERMINE DEGREE OF COMPOSTING OF GROUND, SEPARATED GARBAGE

Test	*Raw Waste*	*Finished Compost*	*Reliability*
pH	5-6	8-9	Indirectly related; reliable only after change pattern established
Chemical oxygen demand	85% reduction		Good reliability
Oxygen consumed	25% reduction		Fair reliability
Total organic (100%—% ash)	80-90%	60-70%	Reliable but requires large, finely ground sample
Transmittance	70%	10%	Indirectly related; reliable only after change pattern established
Starch	75% reduction		Dependent on degree of digestion of only one constituent

oxygen demand is a useful yardstick but is more time consuming and causes problems in the laboratory.

Relative stability, BOD, chlorine demand, and iodine demand tests have not yet been developed so that they are dependable.

Other less scientific but commonly used tests are appearance, odor, and generation of heat. During the composting process the material changes from brown to black and from fibrous to friable appearance. The odor of raw garbage varies from rancid to putrid while that of well composted material has a slightly earthy and sometimes musty odor. Generation of heat as a yardstick is unreliable and depends on such factors as the degree of oxygen available, insulation, seeding, per cent of moisture, pH, time, and surrounding temperature. All but very old compost material will reheat to some degree. To carry the digestion process to the point where reheating will not occur may be impractical and too costly. Development of a reheating test may prove to give a quantitative answer on the momentary rate of digestion.

Yardsticks for rate of digestion that have proven useful include oxygen utilization and carbon dioxide production. If these yardsticks are used on a pilot project or in a full-scale plant it may be necessary to remove a sample of compost to a laboratory-size digester where standard temperatures can be maintained and adequate, continuous stirring provided. These two yardsticks have been the main methods of measurement used in most of the Michigan State University research. Carbon dioxide produced in these experiments was absorbed by bubbling through caustic before the oxygen utilization was measured directly by reduction in volume. The oxygen measurements are easy to make at frequent intervals, whereas the carbon dioxide production requires titration of the caustic solution and replenishment each time. Unless this is done with the utmost care, inaccurate results may be obtained.

On plant-scale experiments oxygen uptake and carbon dioxide production can be reasonably well estimated by making air flow measurements and also frequent analyses of the exhaust gases. Such a procedure, when practical, is strongly recommended as a control in the operation of full-scale plants.

Quality Control

The aim of composting is to make the highest grade compost possible from the raw materials and do it consistently. This means producing a product as uniform or as near uniform as possible. One of the major aspects of quality control has already been discussed in connection with pH control and conservation of nitrogen. Another important aspect is fineness of grind, especially the removal or pulverizing of coarse particles, sharp pieces of glass, and other undesirable objects such as fragments of metal and tin cans. Sometimes plastic objects or even polyethylene bags are objectionable from the point of view of appearance. Quality control is especially important if the material is to be bagged and sold. If it is to be sold in bulk for agricultural purposes, the

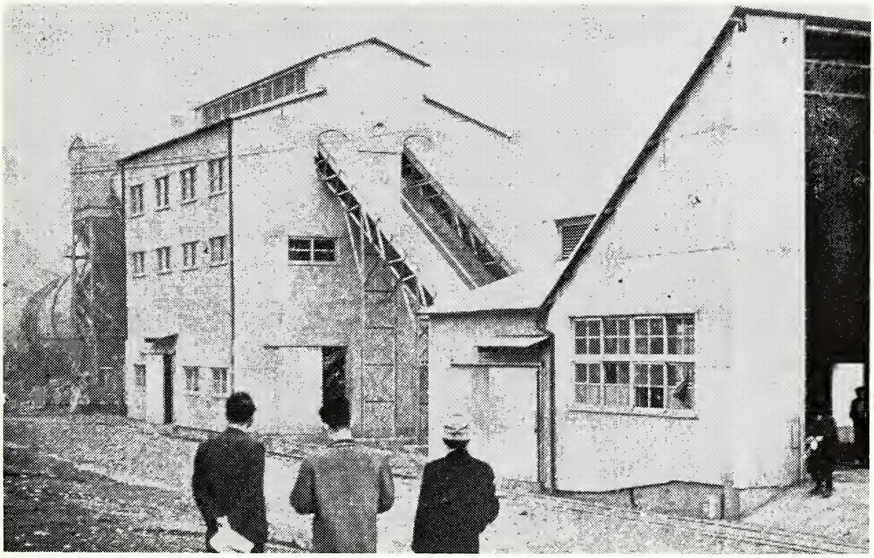


Fig. 128. Composting plant in Tokyo has two digesters.

main thing is to have a uniform end product so that the farmer knows what he is purchasing. If the moisture content varies appreciably, it is well to take this into consideration if the product is sold on a weight basis. It is possible that under some circumstances the producer of large quantities of compost would want to blend the compost material to make fertilizers of different guaranteed qualities. Various elements, including concentrates containing nitrogen, phosphorus, or postassium, might be added.

Bagging

If compost is to be sold in small quantities and at high prices, certain of its qualities must be carefully controlled; it must be dried; and finally it must be attractively packaged. Experience indicates that unlined bags deteriorate rapidly unless the compost is reduced to less than 10 per cent moisture. Even with a low moisture content, bags will deteriorate in 6 to 12 months, especially if they are stored in a damp place, because of the bacterial action of the compost material. One, five, and ten pound sacks are frequently made of polyethylene or plastic lined paper. Compost of 15 to 25 per cent moisture can be used in this type of container and has a better sales appeal than a 10 per cent moisture content compost, which has a tendency to be dusty. Bagging is usually done by a commercial enterprise rather than the municipality. Cans should be removed from the compost if it is to be bagged and sold on the retail market.

Insect and Odor Control

A properly designed and operated compost plant should have few if any problems with insects and odors. Naturally the trucks bringing partially decayed food to a plant will have some odor and may bring flies and larvae with them. Generally, however, chemical sprays will kill flies that come with the refuse; and most of the odor disappears after the refuse is ground the first time. Once the refuse is seeded and starts to heat, most fly larvae are quickly destroyed. If modified windrow or area composting is used all the refuse along the edges will be turned under at the first turning of the pile; in the meantime there should be sufficient biological activity even at the surface of the pile to discourage flies. On occasion the use of chemical sprays is warranted. Outdoor windrowing with aeration by turning requires much vigilance to control flies.

If there are objectionable odors during the composting process, the plant is not functioning correctly; there is probably something wrong with the aeration system because aerobic microorganisms do not produce unpleasant odors. Correction of the aeration system should correct the odor problem.

Labor and Supervision

Safety and cleanliness of employees are particularly important. There are many conveyers and machines and consequently many chances for employees to be injured. Every precaution should be taken to make each operation as safe as possible. Cleanliness of a plant is not only a matter of health but a matter of morale. Strict housekeeping and maintenance standards from the beginning to the end of plant operations pay big dividends. The selection of a plant supervisor should be made with these two points in mind. The technical features of composting can be taught to him, but he must already have the ability to get employees to practice safety and cleanliness.

Laboratory Tests and Controls

As in the operation of a sewage treatment plant, efficient technical operation of a composting plant depends on routine daily laboratory tests and controls. The usual sewage treatment plant laboratory, with the addition of a few pieces of equipment, is satisfactory for most composting plants. Frequent and rapid determinations of pH, temperatures, moisture, and ash are need. In large plants methods for determining oxygen uptake or carbon dioxide production should be used. Determinations of nitrogen, potassium, phosphorus, crude fiber, volatile solids, carbon dioxide, biochemical oxygen, and chemical oxygen demand are also desirable for

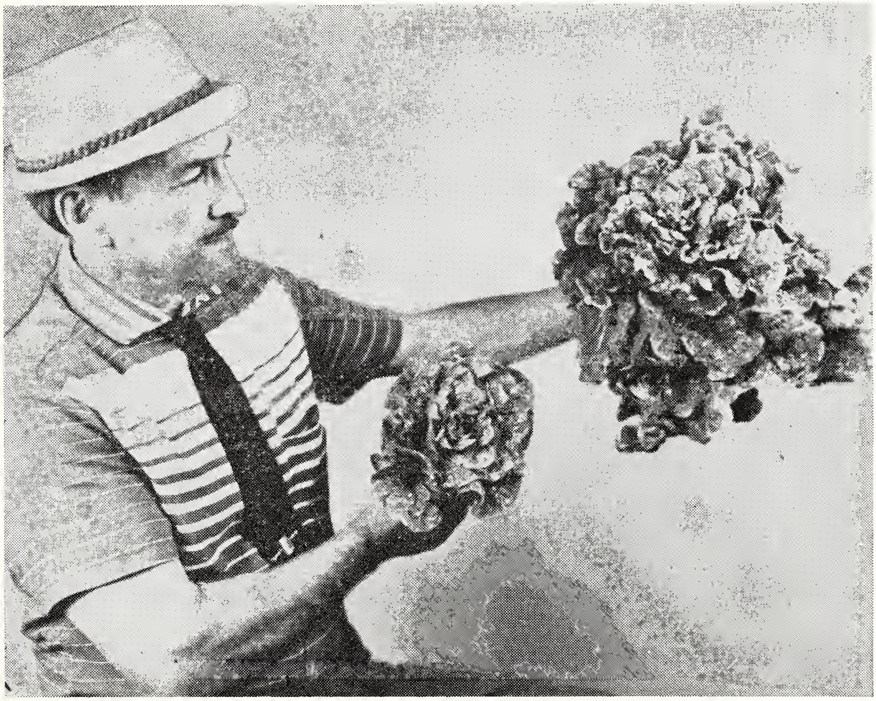


Fig. 129. Compost was used in the soil from which the bigger of these two vegetables was grown, but not in the soil for the other.

medium and large plants or arrangements can be made to have some of these tests run elsewhere as the need arises. In a small plant, routine tests can be made by the supervisor; in a large plant a chemist should be employed. For a relatively new process such as composting it is important that detailed and accurate records be kept and analyzed as the basis for improving plant efficiency. Appendix A tells how to make tests that can be used in analyzing compost.

Marketing Compost

It has been said that under favorable circumstances composting of organic wastes in the United States can be competitive with incineration and sanitary landfill methods of disposal, even if the end product is given away. The real economy of composting comes, however, if the end product can be sold for a fair price. Municipal experience in the sale of sewage sludge is a poor basis for judging how high a price good compost will bring.

Until farmers have personal experience with a product they are likely to be unwilling to pay much for it. It will take time to acquaint potential buyers with compost, determine the value of it in any area, and build up a demand for it. It is unrealistic to think compost can at first be sold at high prices or that all of it can be sold in small quantities to back yard gardeners. Initially a large amount of compost must be sold to farmers at about the cost of production. A realistic economic analysis of a compost plant must be based on this premise, although better markets may develop later.

Retail sale and distribution of compost can probably best be done by private enterprise rather than by a municipality. Bids should be taken on a percentage basis or some other equitable basis or a contract negotiated with a private seller. A long-term contract is probably desirable so that heavy initial promotion costs can be distributed over a long period. An arrangement for selling the compost on a sliding scale basis, with a lower initial cost or percentage, until a demand has been created, has merit.

Ultimately, commercial fertilizer companies will probably be the main distributors of compost. They may sell a wide variety of enriched products that use an organic base rather than an inorganic inert base.

On-Site Composting of Kitchen Wastes

Although many people have back yard compost piles, indiscriminate disposal of kitchen wastes by this method encourages breeding of flies and rats. It is difficult if not impossible to do a good job of home composting without first shredding or grinding the wastes. It is also necessary to mix them with dry porous material if the faster, more efficient aerobic composting method is to be employed.

An anaerobic or semi-anaerobic approach to kitchen waste digestion has been used with varying degrees of success in limited parts of the country in recent years. Essentially it consists of digging a hole about 24 inches in diameter and 20 to 30 inches deep in which a bottomless can with a tight cover to exclude flies is put. If the metal extends 18 to 20 inches below the surface of the ground, rodents are discouraged from burrowing into the decomposing wastes. An installation of this kind works best in dry, porous soil; food wastes shrink and decompose to about one-quarter of their original volume. If food wastes for a family of six are composted, the compost material should be removed every 8 to 14 months. Because it is odorous, it must then be buried or composted elsewhere by mixing with leaves or garden wastes. Rusting of the metal container and the problems of digging and removing the material are the major disadvantages.

This way of disposing of kitchen wastes may be used temporarily in surburban areas but is not recommended as a replacement for refuse collection and disposal by other means nor is it recommended for use in urban areas.

10 SALVAGE AND RECLAMATION

A question often raised that confounds municipal officials responsible for refuse disposal is "Why can't we adopt a method of disposal that produces revenue?" This is usually followed by a quotation from an article in which a new salvage or reclamation method is described or by quoting statistics reported by a city that has found salvage practical because it has a local market for salvage materials.

Salvage and reclamation as a disposal method should be carefully considered and a decision made on the basis of engineering and cost studies. Municipal officials must not lose sight of the primary objective of a disposal program—that it be efficient and nuisance-free for the public. The best revenue producing disposal methods are usually those that are "extra-curricular"—that neither jeopardize nor seriously interfere with the primary disposal methods.

Particularly in large cities, public works officials are justifiably apprehensive of reliance on a disposal method that depends upon fluctuating and sometimes nonexistent markets for salvage or refuse by-products. If the markets collapse, the city may find itself with quantities of refuse and no method of disposal except an emergency landfill a long way from the city. In the past, market prices for salvage have not kept pace with the labor costs involved, and unless there is a reversal of this trend, municipal officials will probably continue to take a dim view of salvage and reclamation as a sound method of disposal. On the other hand, the amount of refuse that must be collected and disposed of by the municipality is influenced by the amount that is salvaged and sold by private interests. When prices for salvage are high, the amount of refuse a city must collect and dispose of can be decreased significantly.

Small cities, where it is not too difficult to get a site for a landfill quickly if the emergency arises, have greater latitude in using revenue producing disposal methods and depending on the market for salvage. In fact, sometimes the city that salvages or reclaims refuse makes a real contribution to the conservation of natural resources.

Changes in salvage practices over the past 50 years are evident from experiences in New York City. At the turn of the century, several large-scale salvage operations were carried on at Barren Island, Rikers Island, and later at Staten Island. Reduction plants processed food wastes, dead animals, and fish for the production of glycerine, oils, fertilizers, and animal hides. Although each of the plants was successful initially, by 1915 all had been abandoned, not only for economic reasons but also because of the uncontrollable nuisances they created.

Fig. 130. If some parts of refuse are salvaged, the amount that must be disposed of by municipal agencies is decreased. Metals are frequently salvaged after refuse has been taken to a sanitary landfill site.

More recently the city awarded contracts annually to private bidders for salvage and reclamation privileges at some 20 landfill sites, incineration plants, and marine transfer stations. The operations became less and less attractive over the years, however, and interference with normal disposal operations, the nuisances created, and the declining salvage market caused the discontinuance of the operations.

New York City also sells ashes that it collects from schools and apartment houses for use as fill material and for construction work. Gross annual revenues for the city from the sales averaged $14,000 a year between 1950 and 1955 but had decreased to only $6,300 by 1959.

Salvageable Materials and the Market

Most salvageable materials are found in rubbish, although garbage and ashes also contain some. Householders are sometimes asked to keep tin cans and bottles, for instance, separate from other rubbish because they have resale value. And during wartime householders have been asked to separate ferrous metals, aluminum, rubber, and tin cans from other refuse.

Of the many items found in rubbish, some have resale value and some have little or none. Those that may have resale value include rags, newspapers, mixed papers, cardboard, books and magazines, bottles, rubber, ferrous metals (including tin cans), nonferrous metals, and glass. Articles with no resale value include leather, enamelware, excelsior, mattresses, matting, linoleum, sawdust, straw, dirt, synthetic fabrics, and plastics.

In combined refuse materials of value may include garbage, bones, ashes, and cinders. The amount of refuse of this kind has been decreasing for a number of years, however, partly because of the use of gas for

Table 34

ANALYSIS OF HOUSEHOLD RUBBISH IN THE DISTRICT OF COLUMBIA, BY SELECTED MONTHS IN 1914 AND 1915

(Per cent by weight)

Material	*Nov.*	*Dec.*	*Jan.*	*Mar.*	*May*	*June*	*July*	*Aug.*
Newspaper	10.4	17.8	19.5	16.1	15.6	17.2	17.0	16.0
Manila paper	6.6	12.7	7.0	9.5	8.7	7.3	12.1	13.4
Cardboard	0.8	9.4	11.7	10.5	9.7	6.9	10.9	12.8
Books	4.4	3.0	2.4	2.4	3.3	3.2	1.4	5.6
Mixed paper	16.6	4.4	3.1	5.0	4.6	2.8	2.4	2.6
Rags	5.9	3.7	4.5	5.2	7.2	4.3	5.0	5.7
Wood	1.2	7.4	1.4	2.8	2.6	4.1	3.6	4.1
Leather	1.5	0.2	0.4	0.7	1.2	0.2	1.0	1.1
Rubber	0.3	0.3		0.3	0.5	0.0		
Screenings		4.6	18.5	13.4	10.4	18.6	12.3	11.1
Tinware	10.2	7.3	11.7	13.6	8.8	6.6	5.6	6.4
Enamelware	0.4	0.4	0.1	0.4	0.3	5.0		0.1
Metals	1.8	0.6	0.3	0.8	1.3	1.1	0.8	1.5
Bottles	11.0	8.1	7.7	9.0	7.7	8.3	8.4	7.2
Broken glass	3.8	3.5	4.0	4.7	5.2	4.3	4.8	3.5
Excelsior		0.7	0.3	0.8	0.7	0.1	0.7	
Mattresses	5.2	1.1			0.3	0.0	0.7	0.1
Matting	3.1	0.8	0.1	0.3	1.6	1.5	1.4	
Linoleum	0.7				0.3	0.1		0.1
Straw			0.4			0.1		
Dirt	16.1	14.0	6.9	4.5	10.0	8.4	11.5	8.7
TOTALS:	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

heating, packaging of frozen food, and increased use of home garbage grinders. The results of an analysis of household rubbish in the District of Columbia in 1914 and 1915 are given in Table 34 and the results of analyses of household and commercial rubbish made in the District in 1956 are given in Table 35.

Rags

Rags are one of the most staple items of value in refuse. The *Waste Trade Journal,* reporting on prices per 100 pounds of mixed white cotton rags for 1933 through 1957, showed that prices did not fluctuate as widely as they did for paper, for instance. The high for rags was $8.40 in 1951; the low, $1.75 in 1955.

Salvage of rags by refuse collectors and scavengers has also substantially reduced the number of them that are taken to municipal incinerators and landfills; during the twenties rags were approximately 5 per cent by weight of household refuse collected by municipalities; by 1956 they were only about 1 per cent.

Paper and Paper Products

Paper and paper products make up the largest proportion of salvageable materials in refuse in the United States and the amount is increasing.

TABLE 35

ANALYSIS OF HOUSEHOLD AND COMMERCIAL RUBBISH IN THE DISTRICT OF COLUMBIA, BY SELECTED DAYS, 1956[1]

	Household Rubbish				*Commercial Rubbish*	
	May 30, 1956		*December 5, 1956*		*May 30, 1956*	
	Per Cent by Volume	*Per Cent by Weight*	*Per Cent by Volume*	*Per Cent by Weight*	*Per Cent by Volume*	*Per Cent by Weight*
Paper products	59.7	60.4	77.3	68.3	66.7	71.4
Metal, cans	19.4	13.1	9.1	10.8	14.8	11.1
Glass	11.9	16.3	7.5	11.5	11.1	12.7
Wood	6.0	8.4	1.5	4.2	3.7	3.2
Rags	1.5	.8	.8	.5	3.7	1.6
Leaves	..	..	3.0	3.5	..	..
Miscellaneous	1.5	1.0	.8	1.2	..	..

[1] Samples from a complete dry-weather truck load (approximately 20 yards) of uncompacted rubbish collected in open trucks and separated into categories; each category weighed separately and volume approximated.

Their market value, however, probably fluctuates more than for any other salvageable material. At times there is practically no market at all. Many municipal officials, particularly in large cities, have been faced with the problem of disposing of baled mixed paper that could not even pay freight charges to a paper mill.

The *Waste Trade Journal*, reporting prices per 100 pounds for mixed paper between 1938 and 1957, showed a high of $1.55 in 1951 and a low of 3¾ cents in 1938. In 1957, however, the high was only 40 cents, which was not in line with increased labor costs.

The same was true for folded newspaper. Prices per 100 pounds ranged from a high of $1.75 in 1951 to a low of 11¾ cents in 1938. In 1957 the high was only 70 cents, however.

Tin Cans

Tin cans and scrap metal are among the most important materials that can be salvaged, either before or after incineration. However, local markets for tin cans vary considerably and there has been some controversy over whether there is a market for them.

During World War II many cities requested householders to clean and flatten tin cans and the city collected them separately and shipped them to detinneries. Both tin and ferrous metal were recovered in this way. Two problems were—and are—the expense of separate collections and the inability to collect enough cans for carload shipments, which are necessary because the cans cannot be baled for this type of processing.

If tin cans are salvaged from incinerator residue after being subjected to temperatures of from 1,400° to 2,000° F., sufficient stannic-oxide remains on the cans so that they are not always acceptable at open-hearth steel mills. On the other hand, tin cans that go to steel mills can be baled and shipped more economically than those that go to detinneries.

There is also a limited market at much lower prices for baled tin cans to be used for sash weights and other crude metal production.

There is a somewhat bigger market for tin cans used in copper precipitation processes, but most plants for that process are in the southwestern part of the United States and are too far away for some salvagers. Furthermore, tin cans cannot be baled if they are to be used for this purpose.

A California salvage company, reporting on the market for tin cans for copper precipitation, said:

> Precipitation iron is made from old, discarded tin cans and is sold to the copper mines throughout the southwest for the precipitation of copper. This material must be well burned, thoroughly cleaned, and shredded in order to be acceptable to the mines. The mining companies generally purchase this material on a long-term contract and shredded cans are not normally handled by the scrap industry. The price of precipitation iron is a matter of negotiation between the buyer and seller and is not affected by the scrap market. It must be understood that precipitation iron is a processed material and that ordinary incinerator cans or burned cans are not acceptable. The material must be completely free of ashes, oxide, scale, etc., and must be properly cleaned and shredded.
>
> Freight charges on "shredded cans" are very high due to the light weight of the material and it is not practical to ship great distances. The salvage and processing of tin cans for the copper mines is limited to the southwest area because of this freight problem. It is our opinion that freight charges on shredded cans originating in the central and eastern parts of the nation would result in a delivered cost that would not be acceptable to the mines.

In 1959 there apparently was no foreign market for baled tin cans. Furthermore, steel mills ordinarily will not buy bundles of metal that include tin cans. In fact, most mills reject bundles of scrap metal if it is evident they contain any tin coated stock.

Obviously, each city must carefully consider the practicality of salvaging tin cans. The resale market for them would soon be glutted if all cities salvaged them and if they continue to be unacceptable for open-hearth use.

Bottles and Rubber

Prices for bottles, cullet (broken glass from glass manufacturers), and rubber also have not kept pace with labor costs, and they require considerable grading if they are to bring a reasonable price.

A California salvage company reported in 1959 that it does not wash or process cullet but delivers it to a firm that does that work. The 1959 price for flint cullet was $9 a ton and for amber cullet $8 a ton, including the cost of delivery to the processor. The company also reported that it salvaged only soft drink and other deposit bottles and that bottle salvage was only a small part of its operation. The 1959 price for bottles was reported as between $22 and $30 a ton.

Salvage as a Principal Disposal Method

Salvage can be a principal means of "disposal" and all of the refuse in a community can be examined and sorted for salvageable materials, or it can be a "side-line" for another method of disposal.

Few municipalities have attempted "all-out" salvage of either rubbish or combined refuse, and most of those that have tried have abandoned their efforts. However, various types of plants were built for the purpose: those in which salvageable materials in rubbish were removed from moving belts and the unsalvageable materials disposed of at incineration plants or landfills; those in which garbage was reduced to grease and fats; and those in which garbage is composted. (Composting is covered in Chapter 9.)

Rubbish Salvage

A rubbish salvage plant in Washington, D.C., was operated on a continuous belt principle. Rags, paper, cardboard, and tin cans were baled; and cullet, bottles, nonferrous metals, and rubber were picked and graded. The plant initially was operated by a private contractor but was taken over by the city and operated by it for about 10 years before it was destroyed by fire and abandoned in 1928.

A more modern salvage plant was built in Detroit in 1945 but it also was abandoned—in 1947. The Detroit plant was run on the gravity principle. Refuse was dumped into a pit and two electric cranes picked up the refuse from the pit and loaded two hoppers feeding to skip hoists. The skip hoist elevated the refuse to the top of the building and discharged it onto a bar screen. As the material slid down the inclined screen, the ashes and other fines were separated and fell into a hopper.

Screened material fell onto a belt conveyer. Tin cans and other magnetic metallics were removed by a magnetic pulley. The tin cans were passed through a shredder, elevated by a conveyer to a storage hopper, and loaded into railroad cars by gravity.

The rest of the refuse was discharged onto a wide picking belt. Paper and cardboard were picked off and dropped to a baler located on the floor below; rags were picked off by grades and also baled. Glass was removed by grades and dropped into hoppers below; nonferrous metals were also salvaged. The last step was to remove bricks, concrete, and similar materials. The residue was then discharged from the picking belt onto a small conveyer belt, which carried the residue to an incinerator plant where it was burned.

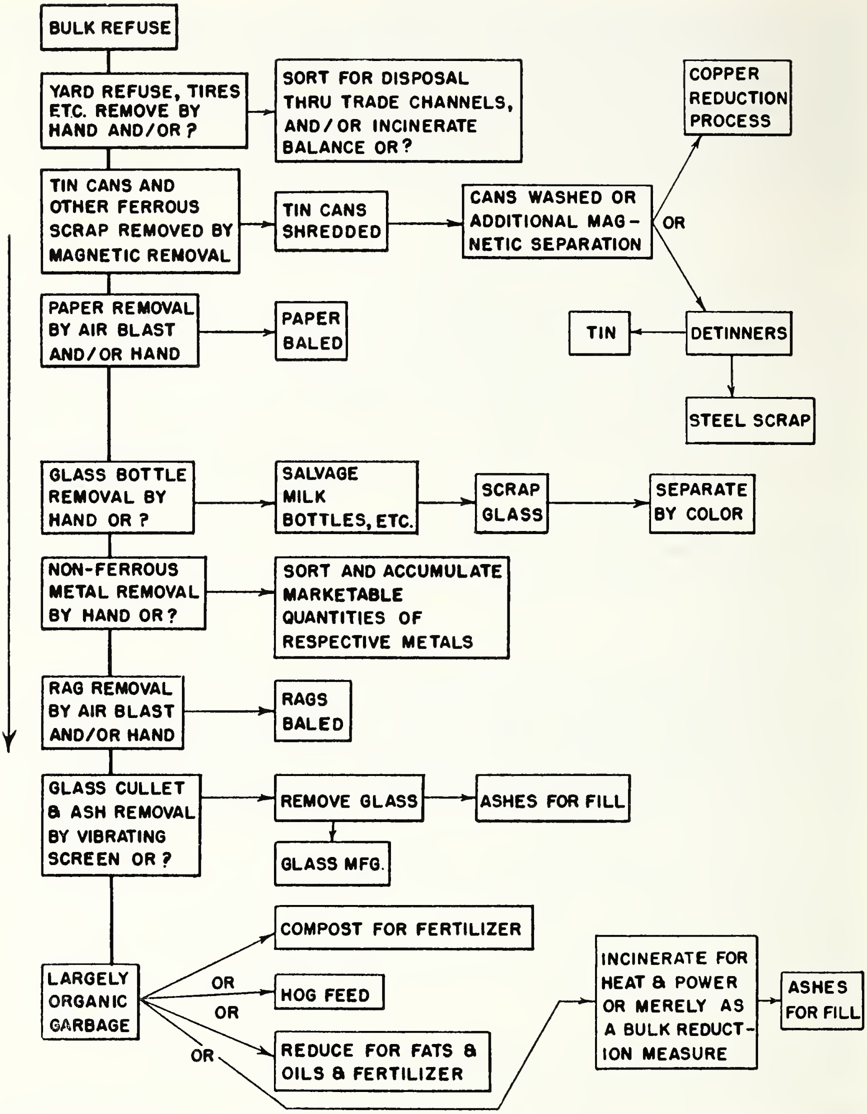

BULK REFUSE
YARD REFUSE, TIRES ETC. REMOVE BY HAND AND/OR ?
SORT FOR DISPOSAL THRU TRADE CHANNELS, AND/OR INCINERATE BALANCE OR ?
COPPER REDUCTION PROCESS
TIN CANS AND OTHER FERROUS SCRAP REMOVED BY MAGNETIC REMOVAL
TIN CANS SHREDDED
CANS WASHED OR ADDITIONAL MAG-NETIC SEPARATION
OR
PAPER REMOVAL BY AIR BLAST AND/OR HAND
PAPER BALED
TIN
DETINNERS
STEEL SCRAP
GLASS BOTTLE REMOVAL BY HAND OR ?
SALVAGE MILK BOTTLES, ETC.
SCRAP GLASS
SEPARATE BY COLOR
NON-FERROUS METAL REMOVAL BY HAND OR ?
SORT AND ACCUMULATE MARKETABLE QUANTITIES OF RESPECTIVE METALS
RAG REMOVAL BY AIR BLAST AND/OR HAND
RAGS BALED
GLASS CULLET & ASH REMOVAL BY VIBRATING SCREEN OR ?
REMOVE GLASS
ASHES FOR FILL
GLASS MFG.
COMPOST FOR FERTILIZER
LARGELY ORGANIC GARBAGE
OR
HOG FEED
OR
OR
REDUCE FOR FATS & OILS & FERTILIZER
INCINERATE FOR HEAT & POWER OR MERELY AS A BULK REDUCT-ION MEASURE
ASHES FOR FILL

Fig. 131. Flow chart showing processing of refuse for salvage. (Reprinted with permission of Armour Research Foundation.)

Garbage Reduction

The method of garbage disposal known as reduction was at one time popular and productive of revenue. Most reduction plants were built before World War I but few continued in operation afterward.

In the reduction process, garbage was cooked with steam in digesters, the grease was extracted by percolating naphtha through the cooked garbage, and the solvents were distilled for further use. If solvents were

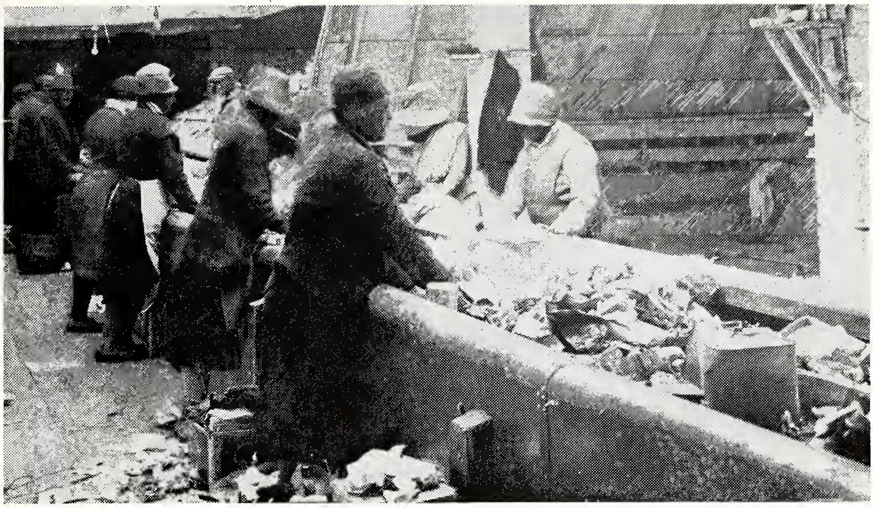


Fig. 132. Salvageable refuse is being taken from this picking belt at a now-abandoned salvage plant.

not used, the cooked garbage was subjected to high pressure in hydraulic or screw presses to extract the grease. The residue, called tankage, was used as feed for livestock, as fertilizers, and as boiler fuel. The grease itself was sold primarily to soap manufacturers.

Odors from the garbage and gases from the cooking made the plants so offensive that they usually had to be located a long way from a city, which increased the costs of getting the garbage to them. The plants were expensive to operate because of high labor costs, rapid deterioration of equipment, and the need for large quantities of steam.

Rochester, New York, and Philadelphia had municipally operated reduction plants, with Philadelphia one of the last to abandon operations (1959). Plants were also closed in Syracuse, New York, in 1956 and in Indianapolis in 1951.

In other cities reduction plants were operated by contractors—in New York, Pittsburgh, Washington, Chicago, and Cincinnati. Some privately operated plants were taken over by the city government when the contractors could not operate them profitably. This happened in New York, Washington, and Chicago.

Why is reduction obsolete as a method of garbage disposal? The national economy and the habits of the people have brought it about. Wages have increased without compensatory automation in reduction plants. Not only has the amount of garbage collected decreased on a per capita basis but the grease content of garbage has also decreased. When reduction plants were profitably operated the grease content of garbage was often in excess of 5 per cent. By 1948 it had gone down to less than 3 per cent.

Furthermore, the market for grease has declined considerably. Soap

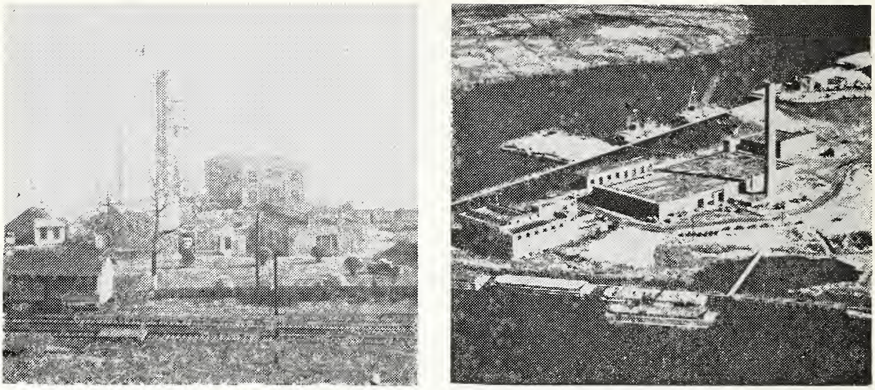


Fig. 133. Abandoned reduction plants at Cherry Hill, Virginia (left), and Fresh Kill, Long Island, New York (right).

manufacturers at one time were the principal buyers. Today, however, detergents have taken the place of many soaps and they are made from synthetics or petrochemicals.

Salvage as a principal means of disposal has not in general been found satisfactory and is not acceptable in most United States cities—from aesthetic, sanitary, and economic standpoints.

Partial Salvage

Great quantities of material from rubbish and garbage are salvaged and resold today, in spite of the failure of the so-called all-out salvage plants. Various means are used.

At the Source

Both municipal and private collectors remove saleable materials such as rags, cardboard, and magazines during refuse collection. And although many cities have strict rules against this practice because it delays collections, it has not been entirely eliminated.

In a number of large cities scavengers are permitted to separate salvage materials from other refuse put out for collection or to collect such material put aside for them by householders and businesses.

Many businesses, hotels, and apartment houses also permit or engage in salvage of paper and cardboard. When prices for paper are high the Salvation Army, the Boy Scouts, the public schools, and others sometimes collect newspapers and magazines from householders and sell them to raise money for their activities. Many public officials responsible for refuse collection and disposal think that voluntary collections are the most practical method of conducting a salvage program. Without voluntary unpaid workers, house-to-house collections would not be economically justified. Indeed, campaigns to salvage metals during the war would not have been "self-supporting" without volunteer workers. Some authorities involved in the wartime campaigns believe that if conservation of metals is the goal—not low-cost disposal—it would be better to separate the materials at the source and collect them in compartmented trucks.

At Incineration Plants

Experiences in New York and Washington and other cities that operate large incinerators indicate that salvage of tin cans and other materials at the incineration plant often interfere with normal operations and in addition cause an unsightly appearance. Materials other than refuse components often can be salvaged at an incineration plant, however.

Residue. Incinerator residue is, roughly, a combination of ferrous metal, glass slag, inert ash, and unburned organic and inorganic matter, the amount depending upon the efficiency of the burning process and the operating procedures. If combustibles and noncombustibles are collected separately so that metal and glass are not included in the refuse taken to the incinerators, the amount of incinerator residue is less than if they are included. But metal and glass are never completely eliminated from refuse, and there are two schools of thought about whether year-around separate collections to reduce the amount of noncombustibles taken to incinerators are economical. There is some justification for the belief that tin cans and bottles cause voids in refuse, that the voids accelerate the burning of combustibles, and that metal salvage after incineration is simple and practical.

If there is a good market for low-grade scrap metal, salvage of ferrous metal from incinerator residue has three advantages: it brings in revenue for the city, it does not interfere with the basic refuse disposal operation, and the metal does not take up space in a landfill.

Incinerator residue can also be used to good advantage for land reclamation and for access roads to landfills if there is not a market for it.

Fly Ash. When trapped by dry-type methods, fly ash is another type of incinerator residue. Its potential uses as an additive for concrete and as a base for fertilizer have not been fully explored. The use of steam plant fly ash as a concrete additive, however, was studied recently by engineers of the Tennessee Valley Authority. Fly ash recovered by mechanical collectors in TVA steam plants replaced 20 per cent of the cement and 10.5 per cent of the sand necessary for the concrete at Wilson Dam Lock. The cement produced had a 28-day compressive strength of 4,500 pounds per square inch.

The TVA report pointed out:

> Fly-ash is an artificial pozzolan. A pozzolan is defined as "siliceous or siliceous and aluminous material like volcanic ash, which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties." Calcium hydroxide is liberated during the hydration of portland cement, and pozzolans combine with this liberated lime to form a hard, durable compound which is mostly insoluble silicates. Natural pozzolans, such as volcanic ash, have been used for over 2,000 years. A mixture of

volcanic ash and calcined limestone formed the hyraulic cement used in such enduring Roman structures as the Pantheon in Rome.

The chemical and physical characteristics of a sample of fly ash as determined by analysis by the Poz-O-Pac Company in 1959 are shown in Table 36.

TABLE 36

PHYSICAL AND CHEMICAL ANALYSES OF INCINERATOR FLY ASH, 1959

Physical		*Chemical*	
Sieve No.	*Per Cent Passing*	*Component*	*Per Cent of Total*
100	88.3	SiO_2	50.28
200	62.9	Fe_2O_3	3.16
325	55.5	B_2O_3	29.85
Ignition loss	3.96	CaO	8.23
		MgO	2.86
		Sulfur	0.80
		Other	0.86
		Ignition loss	3.96

The use of incinerator fly ash as a pozzolanic base material with pressure hydrated lime and aggregates is acceptable to highway departments. When used in the correct proportions, fly ash, hydrated lime, and aggregate form a concrete-like mass that has proved a superior base material for roads, airport runways, and parking lots.

A mix of 5 parts of lime, 10 parts of incinerator fly ash, and 90 parts of aggregate was tested and found to average a strength of 530 pounds per square inch; and a mix of 5 parts of lime, 15 parts of incinerator fly ash, and 85 parts of aggregate had an average strength of 780 pounds per square inch.

Other uses for incinerator fly ash include:

1. In combination with hydrated lime for mud jacking of concrete slab floors, streets, sidewalks, curbs, and gutters.
2. Magnetic oxides have been separated from fly ash to improve them for use in concrete. The iron oxide obtained from the separation is also used as a densifier for concrete, especially in the manufacture of concrete pipes or pipe covering to prevent flotation of lines in marshes and under water.
3. As an additive and vehicle in the manufacture of commercial fertilizers. Some of the trace elements found in fly ash have been found to be beneficial for agricultural purposes.
4. As a sand blasting material where a highly polished surface is desired, such as turbine rotar blades.

The satisfactory use of fly ash depends largely upon its quality. If it has a low carbon content (less than 12 per cent) it performs excellently in any of the combinations listed above.

Waste Heat. Heat from incinerator furnaces is sometimes sold to private businesses and utilities companies or is used in sewage disposal plants and other public facilities. The question of whether to try to use waste heat from incineration plants should be carefully considered. At first glance it appears that there is little justification for wasting the heat generated by the furnaces. But the question usually must be resolved on the basis of local conditions—power rates and the need for the steam by users within a reasonable distance of the plant.

It is usually practical to sell heat only if the buyer is near the incineration plant and is willing to take it on an "as available" basis, however, since the steam is not available in the same quantities at all times. The furnaces must be shut down for repairs and maintenance on weekends and at other times, for fly ash removal, and sometimes simply because it is not economical to operate the incineration plant on weekends and holidays. If steam is sold, it is almost necessary to have auxiliary furnaces to use at such times and to store some refuse to be burned on holidays and weekends.

Incineration plants are successfully used as steam generating plants, however. Examples are those in Atlanta and Miami. And in New York City a heat recovery plant has been successfully operated for more than 20 years at one of the large incineration plants adjoining a sanitation department garage. On the other hand, a small New York plant that generates steam for nearby power users, although in operation for a number of years, is economically questionable.

The average heat value of refuse burned in New York incinerators on a "dry inert-free" basis is estimated at 8,000 B.T.U. This heat value on an "as received" basis is about 4,500 B.T.U. Normal incineration operations will use from 33 to 67 per cent of this thermal value, leaving an excess of from 1,000 to 3,000 B.T.U. Because of loss in heat transfer, it is estimated that 1 pound of refuse will produce from 1 to 2 pounds of steam. A New York City incinerator, it is estimated, safely produces about 83,000 pounds of steam an hour when operating at 80 per cent of its design capacity.

It is evident that local conditions must be right to profitably use waste heat as a method of salvage. The fact is that surprisingly few municipalities have found it economically feasible or practical to include equipment for waste heat utilization in modern high-temperature incineration plants.

While a case for steam production for central heating can perhaps be justified where there is a relatively large demand for it close to a large incinerator, a case for including facilities for waste heat use in most plants is complicated by several factors:

1. Requirements for power for operating the incineration plant itself are not great enough to warrant installing facilities for generating steam for the plant alone.
2. Local power rates are sometimes so low that costs for capital outlay, operation, and transmission at relatively small incineration plants (even with "free" fuel) make steam generation too costly to be

competitive with other producers of it. (Fuel costs for large, urban steam generating plants are usually 3 to 4 mills per kilowatt hour.)

3. The need for a constant supply of power usually requires either installation of auxiliary equipment or operation of the plant 24 hours a day, 7 days a week.
4. Boilers and other equipment used to generate steam require licensed operators, which increases labor costs.

Waste heat from an incineration plant can often be used to advantage if the plant is combined with the sewage disposal plant, however. The hot gases from the incinerator furnaces can be used in the flash sludge dryers in the sewage disposal plant and the sludge can be returned to the incinerator to be burned if it is not processed for fertilizer. Furthermore, noxious and odorous gases from the sewage disposal plant can be burned in the incineration plant furnaces before they are discharged into the atmosphere.

At Landfill Sites

Landfills themselves are reclamation projects, since refuse is used to fill pits, quarries, marshes, and other land that is unusable unless it is filled.

In addition, refuse materials that are resaleable are often salvaged at the site. At landfill sites, where there is considerable opportunity for partial salvage without interference with fill activities, the appearance of the grounds is often unsightly. The salvage pickers are often slovenly looking, and in some places small children have been permitted to help with the picking. As long ago as 1921 some cities recommended that "no salvaging should be allowed at the dump at any time, except by city employees." Under controlled conditions, however, salvage at landfills may be satisfactory and bring in revenue for the city.

If salvage operations are carried on at landfills, every effort should be made to avoid interference with fill operations. The salvage area should be fenced and monitored to avoid unsightliness caused by windblown paper, and storage of salvage materials should be strictly controlled by the city. An advantage of salvage at landfills is that bulky objects such as oil drums and bedsprings are not put into the fill, which makes the fill more stable.

In San Francisco, private refuse collection trucks unload salvageable materials that have been separated during collection at a salvage yard just outside the site of a city operated landfill.

Rendering

The rendering process is somewhat like the reduction process, but it involves animal refuse rather than vegetable refuse. Dead animals, fish, and wastes from slaughter houses and butcher shops are used. Unlike the products of reduction, however, the market for rendered fats has not been lost and the raw materials have not decreased.

Cities do not operate rendering plants but many use them to dispose of dead animals. (Large animals have almost disappeared from big cities, except in zoos and at riding academies, but many cats and dogs die or are killed each year and must be disposed of by the city.)

Not much more than 50 per cent of the weight of cattle on the hoof goes to the meat market so the chances are that there will continue to be a supply of raw material for rendering plants. Large packing houses pride themselves on using the animals to the maximum—and for the most favorable market. (Lips and ears of animals are cured in brine for crab bait!)

Among the many products are fertilizers, glues, oils, glycerine, soaps, and detergents. Although these products are in competition with others produced from different sources, that is not a concern of city officials as long as rendering plants stay in business.

Rendering plants usually must be located far from dwellings. Under zoning ordinance provisions they are in the lowest classification. They are often considered nuisances, but they have their place in the nation's economy.

Dehydration of Garbage

The removal of water from foodstuffs to preserve them has been done commercially more or less successfully for many years, although dehydration of garbage to be fed to pigs has been used as a disposal method only on a limited scale.

Commercial type rotary drum dryers that process garbage were experimented with in recent years in Omaha, Nebraska, and jointly in Kansas City, Missouri, and Kansas City, Kansas. Both operations have been abandoned.

TABLE 37

ANALYSIS OF HOUSEHOLD AND RESTAURANT DEHYDRATED GARBAGE, KANSAS CITY, MISSOURI
(By per cent of sample)

	Household Garbage	*Restaurant Garbage*
Protein	10.62	11.70
Fat	8.01	16.75
Fiber	9.01	10.10
Ash	27.62	24.96
Moisture	7.26	4.50
Nonfibrous extract (N.F.E.)	39.45	31.99
Carbohydrates (N.F.E. plus fiber)	48.46	42.09

There are obvious advantages to businesses in dehydration of foodstuffs but they are not as obvious in garbage processing. In any event, the matter of separate garbage collections and the competition from hog farms that use garbage must be considered in determining whether the method is economical and practical.

Automobiles

A familiar sight along highways on the outskirts of cities is the auto morgue, or "graveyard." When the economy is good, many old cars and trucks end up in such "graveyards." There they are stripped of still usable parts, some of which are no longer available from the manufacturer, and in any event, are cheaper than similar new parts.

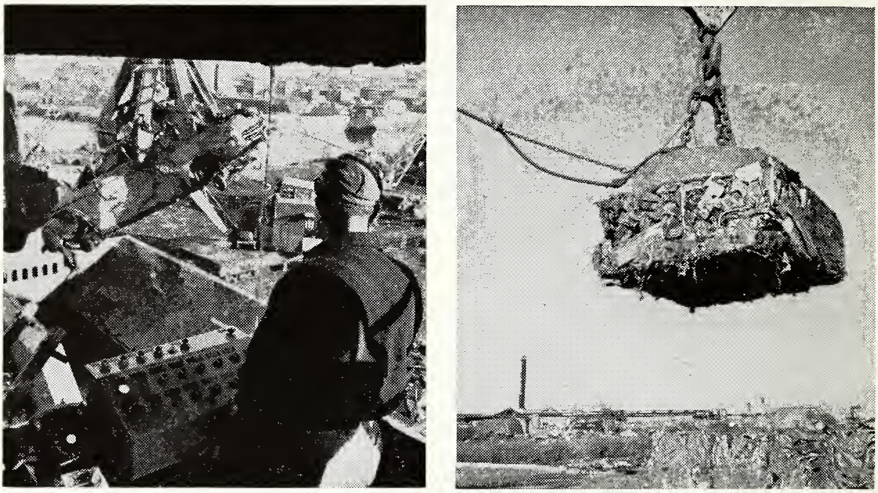


Fig. 134. Automobile bodies that have had the combustibles burned off them make good scrap metal for the steel industry. The baler (left) compresses a whole car to a relatively small size (right).

Although scrap metal from old cars and trucks is sometimes sold to steel mills, the market has been cut by the requirement of the mills that bundles of scrap metal be of certain sizes and that contaminants and some other materials not be included.

Two additions to scrap recovery equipment may help to get scrap metal from cars back into the salvage market, however. One, a special-purpose incinerator, is described in Chapter 6, On-Site Incineration. The other is a large baling press that can compress a whole car body to a bale 2 feet by 4 feet by 5 feet, a size acceptable to steel mills.

Control of Scavenging

Scavenging causes several problems. It often interferes with disposal operations, delays collections, makes disposal facilities unsightly, can be dangerous to workers at the facilities, and sometimes spreads disease.

A city can, by ordinance, prohibit scavenging entirely or it can control it. If a city permits scavenging but controls it, the city frequently issues permits to scavengers. Those who do not have permits scavenge illegally and can be prosecuted. Fines, imprisonment, or both may be prescribed in the law. If a city has a contract with a private company to collect and dispose of refuse, it can control scavenging through its contract. Administrative regulations are usually sufficient to deter city employees from scavenging.

Scavenging can be prevented at least in some measure if fences are put up around disposal facilities and a uniformed policeman is on duty at the disposal facilities to enforce the ordinances against it.

The Future of Salvage and Reclamation

Perhaps the most serious problems in using salvage and reclamation even as a partial disposal method are the lack of stable markets and reasonable prices for salvageable materials. The availability of salvage materials and their relationship to the costs of salvaging and processing materials for the market plus the prices they bring determine whether salvage is practical. The prodigious waste of everyday materials in the United States assures availability of the source of salvage. The question is whether they can be salvaged economically—and even lucratively.

The record indicates that although paper, cardboard, and rags will continue to find their way to mills, most cities do not find it aesthetically or economically practical to use salvage as a principal means of disposal. The trend is toward partial salvage.

11 REFUSE DISPOSAL MANAGEMENT

Management involves planning, organizing, directing, and controlling the various parts of an undertaking so that all components function correctly and cooperatively. Sound management of refuse disposal activities is essential to achieve an efficient, sanitary, reliable operation that is well accepted by the community.

Basic management principles are the same for cities of all sizes but their application varies from place to place, depending on the extent and complexity of the activities and on the way the function is organized and financed.

The pertinent elements of refuse disposal management discussed in the following pages include organization, personnel, reporting, cost accounting and budgeting, and special administrative considerations such as public relations. Planning of refuse disposal facilities has been covered in preceding chapters.

Organization

The basic principles of sound organization that have proved successful in other fields of activity are equally applicable to refuse disposal; yet no single type of organization structure and no standard distribution of responsibilities can be said to be best. The reason is that no two situations are exactly alike and many are widely divergent. Among the many variables found in municipal disposal operations are the methods of disposal, amounts and kinds of refuse, size of the city in population and area, other related operations conducted by the government, use of contractors or private services for collection or disposal, laws or charter provisions, tradition, and even political policy.

Principles of Organization

Organization for refuse disposal in general should be governed by the broad principles that have proved successful in both public and private undertakings. Some of the basic ones are:

1. Lines of authority and responsibility should be clear and definite so that each employee can readily understand his place in the operation, to whom he is accountable, the units or employees under his supervision, and his relationships with other units and employees.
2. Authority and responsibility should flow directly between higher units and those immediately subordinate.

3. Each unit and employee should be given authority commensurate with assigned responsibility.
4. Responsibility should be distributed to units and employees to avoid overlapping, duplication, and dual accountability.
5. Division of responsibility among organizational units according to area, purpose, time, or process should be on the basis of comprehensive consideration of the basic functions of the whole operation.
6. The number of subordinates reporting to a superior should not be greater than he can supervise competently.

Disposal in Municipal Government

The refuse disposal function is ordinarily grouped with other municipal sanitation or public works functions in a major department of the government. The purpose of this arrangement is twofold: first, the chief executive or chief administrator of a city can deal successfully with only a limited number of departments or agency heads; and second, this is the best means by which most municipalities can afford to obtain the necessary high quality professional, technical, and management leadership for public works functions. Linking refuse disposal to other sanitation and public works activities permits easier direction, planning, and coordination by utilizing the specialized engineering, environmental sanitation, and public works skills of organizational unit heads.

A review of practices throughout the United States shows that the refuse collection and disposal functions are included in public works or public service departments in about 60 per cent of the cities, in sanitation departments in about 20 per cent, in street or street and sanitation departments in about 5 per cent, in engineering departments in about 5 per cent, and in various other departments in about 10 per cent.

A great variety of grouping patterns exists within departments. Patterns depend largely on such factors as the size of the municipality, traditional arrangements, and area. In a public works department, a common practice is to include refuse disposal with refuse collection and other functions in a bureau or division of sanitation (occasionally called by a different name, such as refuse collection and disposal, waste disposal, or street sanitation). The other functions may be street cleaning, snow removal, sewer maintenance, sewage disposal, or catch basin cleaning. Occasionally, however, refuse operations are grouped with street maintenance in various arrangements.

A typical large sanitation department would properly include refuse collection and disposal functions in addition to street cleaning and snow removal. Sewage disposal, a major municipal operation in itself; catch basin cleaning; and other related activities might logically be included as sanitary functions. Some large municipalities have separate divisions of collection and disposal.

The internal organization of a refuse disposal unit may be divided according to area, kind of disposal method, or disposal locations. In a small municipality the head of each disposal operation may report directly to the refuse disposal supervisor, or in very small places to the head of the sanitation or similar unit that includes both refuse collection and disposal. Large cities that have various types of disposal facilities may have an incinerator section and a sanitary fill section, for example. District organization, however, may be more important if relatively large areas are involved; in this type of organization all disposal facilities in a portion of the city may be brought together under a district supervisor.

A few municipalities have provided for division of responsibility on an area basis at the top level of a sanitation or similar unit. In such cases, a district supervisor has charge of all refuse collection, refuse disposal, and possibly other functions in his assigned area. Within a district functional divisions are normally established for collection, disposal, and other assigned work.

If either refuse collection or refuse disposal is done by contractors, the organization pattern may be somewhat different from what it is for operation by city forces. If only disposal is done by contract the responsibility for supervising contract work should be with the head of the collection agency or in an echelon immediately above it. If refuse is collected by contract, the city supervisor for this activity may be in the refuse disposal unit, but more frequently he is assigned to the head of a sanitation bureau or division or to a department of public works of which the refuse disposal unit is part.

Staff and Auxiliary Services

Staff and auxiliary services must be provided for a refuse disposal unit regardless of its size or kind. Such services may be furnished partially or completely by the disposal unit itself, for an entire sanitation division or bureau, for an entire department, or for the entire city.

Staff activities as adjuncts to management are carried on in some degree at each level of supervision, performed by a special unit attached to the operation, by a combination unit serving several operations, or by a line officer or his assistant. Staff activities relating to refuse disposal include, among others, planning, research, technical advice and assistance, standardization of procedures and methods, budget preparation and control, employee relations, personnel, public relations, legal counsel, and financing. The organization for some of these activities is described in the paragraphs immediately following and for others in major sections below.

Several staff activities are almost always furnished on a city-wide or department-wide basis, but even in these cases some residual responsibilities may be important enough to justify organizational attention at lower levels. Planning is an example. Over-all planning for refuse disposal may be done by the city planning agency, but the most important immediate aspects of the planning must be done much closer to the function itself—within the disposal unit, in a more comprehensive sanitation unit, or in a still larger department unit. Administrative and operations planning for collection and disposal may also be provided at the department level, but more often at the bureau or division level for collection and disposal. Some planning, of course, is done at all levels, but a separate operations planning unit is seldom justifiable for a refuse disposal unit alone, although one may be created to serve both collection and disposal and possibly other functions. Responsibility for operations planning may also be assigned to the unit that is responsible for research and operation analysis. If planning is not provided in a staff unit it must be performed by line officials in addition to their operating duties.

Technical assistance may be provided by a special technical unit in a bureau or department. Often it is provided by engineering units outside the bureau or even outside the department. Engineers also frequently consult on the design of incinerators and occasionally in connection with other disposal problems. Selection of consultants is usually done by negotiation, since experienced engineering firms will not submit competitive bids. Engineering fees for such services have been fairly well standardized through action of the engineering societies. Choice of a firm to supply technical assistance in refuse disposal problems, therefore, can be made largely on the basis of comparisons of experience records.

Service activities for refuse disposal also may include equipment maintenance and servicing, accounting, preparation of statistical reports, purchasing, stores, and property and plant maintenance. Here again, services may be provided for the entire city government, for an entire department, for a bureau or division, or for the refuse disposal unit alone. Patterns vary greatly, depending upon the size of the city, the number of disposal sites, and many other factors. However, in general few staff or service units are established for refuse disposal organizations alone. Exceptions are plant maintenance, research, and technical assistance in very large refuse disposal agencies.

Cities use outside maintenance or shop services either on a continuing contractual basis or for individual jobs. Private consultants are also retained when qualified engineering or specialist services are not available from the city itself.

Various ways of organizing to provide for staff and service functions may be noted in Figure 135, which shows possible staff or service units attached to successive units in the command line from the city's chief executive through a department head and a bureau to a division of refuse disposal. The decision on whether to create a staff unit, to combine two or more staff activities in one unit, or to assign the duties to a line officer depends largely on the amount of responsibility and work involved. If the work load is small enough so that the line officer can perform staff functions himself, no staff units are created, since staff activities are performed solely to aid the line officer.

Technical assistance may be provided within a refuse disposal unit if a city has a sufficient number of incinerators or sanitary fills to make adequate use of specialists' knowledge. In a small city or one with few disposal locations, technical assistance may be provided by a unit that

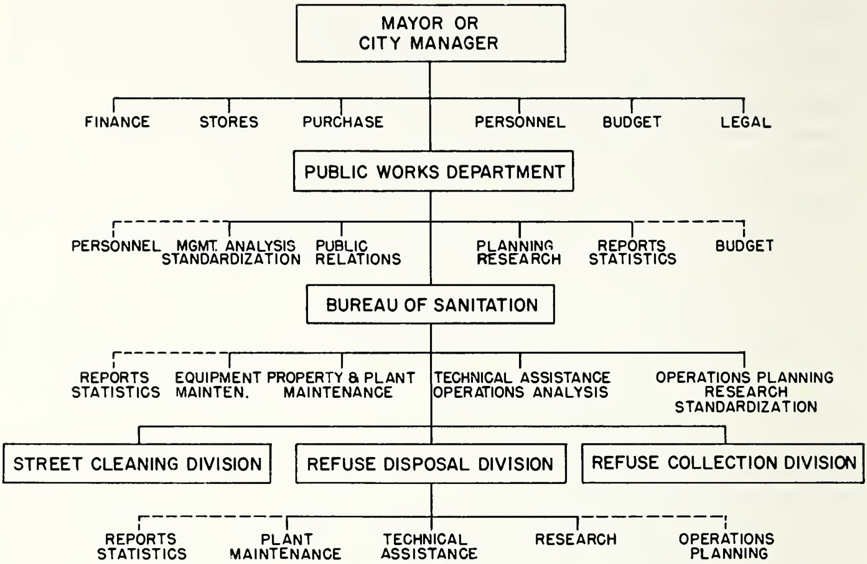

MAYOR OR CITY MANAGER
FINANCE
STORES
PURCHASE
PERSONNEL
BUDGET
LEGAL
PUBLIC WORKS DEPARTMENT
PERSONNEL
MGMT. ANALYSIS STANDARDIZATION
PUBLIC RELATIONS
PLANNING RESEARCH
REPORTS STATISTICS
BUDGET
BUREAU OF SANITATION
REPORTS STATISTICS
EQUIPMENT MAINTEN.
PROPERTY & PLANT MAINTENANCE
TECHNICAL ASSISTANCE OPERATIONS ANALYSIS
OPERATIONS PLANNING RESEARCH STANDARDIZATION
STREET CLEANING DIVISION
REFUSE DISPOSAL DIVISION
REFUSE COLLECTION DIVISION
REPORTS STATISTICS
PLANT MAINTENANCE
TECHNICAL ASSISTANCE
RESEARCH
OPERATIONS PLANNING

Fig. 135. Organization chart showing alternative arrangements of staff and service units for refuse collection and disposal agencies within municipal government.

serves an entire sanitation bureau or division, or again, it may be provided by a unit that also has certain other staff assignments.

Cities that have incinerators or other disposal plants must consider the appropriate allocations of maintenance and rehabilitation activities. Often the plant supervisor has the maintenance responsibility. Sometimes only routine repairs are so assigned and major maintenance is provided as a bureau or departmental service to all installations. Thus, in cities that have more than one incineration plant or other facility a maintenance unit may be created in the sanitation bureau or division to serve the disposal unit, as well as others.

Coordination of Collection and Disposal

The necessity for coordinating refuse collection and disposal operations for ease and effectiveness of management has been pointed out in preceding chapters. Although coordination may be achieved largely through physical and operations planning, good organization also promotes harmonious operations. Coordination is most easily effected when refuse collection and disposal units are located in the same bureau, division, or department.

Disposal facilities should be provided and operations planned so that all refuse can be received promptly and efficiently when it reaches the disposal facility. Disposal units and storage capacity should be flexible enough to meet daily and seasonal variations and all except the most unusual emergencies. Collection activities, in turn, should be planned to provide a reasonably continuous flow of refuse to the disposal facilities.

Coordination is much more difficult when one function is performed by a contractor and the other by the municipality or by another contractor. If only one function is performed by a contractor, smooth operation can be most easily attained by placing responsibility for contract supervision in the municipal agency that is responsible for the other function or in the echelon immediately higher. If both services are performed by contract, the same municipal agency should supervise both. The official or unit responsible for contract supervision should be specifically designated in the contract. Neither the city council nor a committee of the council should supervise such contracts for a number of obvious reasons. The responsibility should be centered in one qualified sanitation or public works employee.

Avoidance of Dual Supervision and Accountability

Refuse disposal operations are not particularly susceptible to awkward interrelationships among municipal services because, in general, the installations are isolated or easily separable and interference is negligible. Nevertheless there are times when the principles of establishing clear lines of authority and avoiding overlapping responsibility and dual accountability have been violated.

The usual interrelationships with collection forces in routing trucks and designating unloading locations at disposal sites or with garages in storing or servicing vehicles, however, cannot be classed as dual responsibility. The collection truck drivers do not come under the authority of the disposal agency any more than they come under the authority of traffic officials when they obey the directions of a traffic policeman or abide by traffic regulations. Normally, the refuse collection unit issues regulations to its drivers to follow the instructions of attendants at disposal locations or at garages. The refuse disposal unit should not, and usually does not, hold itself accountable for collection employees or equipment.

In large cities, instances of dual accountability may occur when greater emphasis is given to equipment care and maintenance than to effective operation. For example, an undesirable, complex, dual supervision situation, which can result from such emphasis, occurred in a large eastern city where the purchase of all automotive and mobile construction equipment is the responsibility of the department of public property. The equipment used for refuse disposal is operated by the automotive section of the sanitation division of the streets department under the direction of the refuse disposal section. In this case a tractor operator who is digging, compacting, and covering refuse in a sanitary landfill operation is responsible both to the automotive section and to the refuse disposal section of the sanitation division. Maintenance of the tractor also is the responsibility of two agencies—the sanitation automotive section for first and second echelon maintenance and the department of public property for major maintenance. Such organization tends to produce conflicts.

There is no real justification for dual accountability even when the purchase and maintenance of equipment is the responsibility of one agency and the operation of it is the responsibility of another. The equipment operators and the equipment should be under the exclusive control of the functional agency once operators and equipment have been assigned to it, subject only to regulations of the equipment agency on the care and handling of the equipment. Most cities have found it more satisfactory to have equipment operators be employees of the functional agency than the equipment agency. The interests of the equipment agency can be adequately protected through the development of regulations that have the full force of orders when issued by line officials of the functional agency.

Examples of Disposal Organization

Typical organizational principals are illustrated by the arrangements in use in municipalities such as Los Angeles; Cincinnati; Winnetka, Illinois; and New York.

The arrangement in Los Angeles is representative of the allocation of refuse disposal to a public works department in a large city, as shown in Figure 136. The function is included in a bureau of sanitation along with refuse collection, sewer maintenance, and sewage treatment. Each of these four functions is carried on by a division of the bureau of sanitation. The refuse disposal division is divided generally on the basis of the

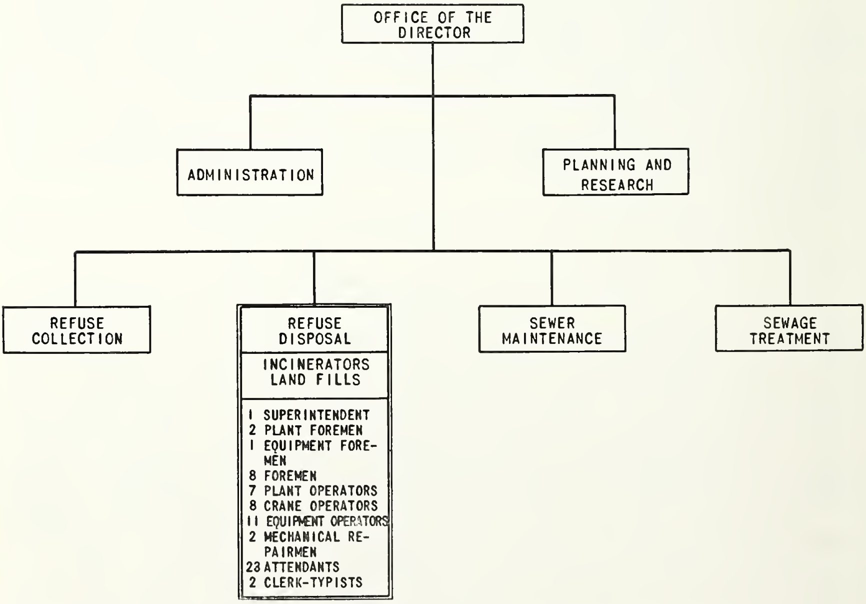

OFFICE OF THE DIRECTOR
ADMINISTRATION
PLANNING AND RESEARCH
REFUSE COLLECTION
REFUSE DISPOSAL
INCINERATORS LAND FILLS
1 SUPERINTENDENT
2 PLANT FOREMEN
1 EQUIPMENT FOREMEN
8 FOREMEN
7 PLANT OPERATORS
8 CRANE OPERATORS
11 EQUIPMENT OPERATORS
2 MECHANICAL REPAIRMEN
23 ATTENDANTS
2 CLERK-TYPISTS
SEWER MAINTENANCE
SEWAGE TREATMENT

Fig. 136. Organization chart, Bureau of Sanitation, Department of Public Works, Los Angeles.

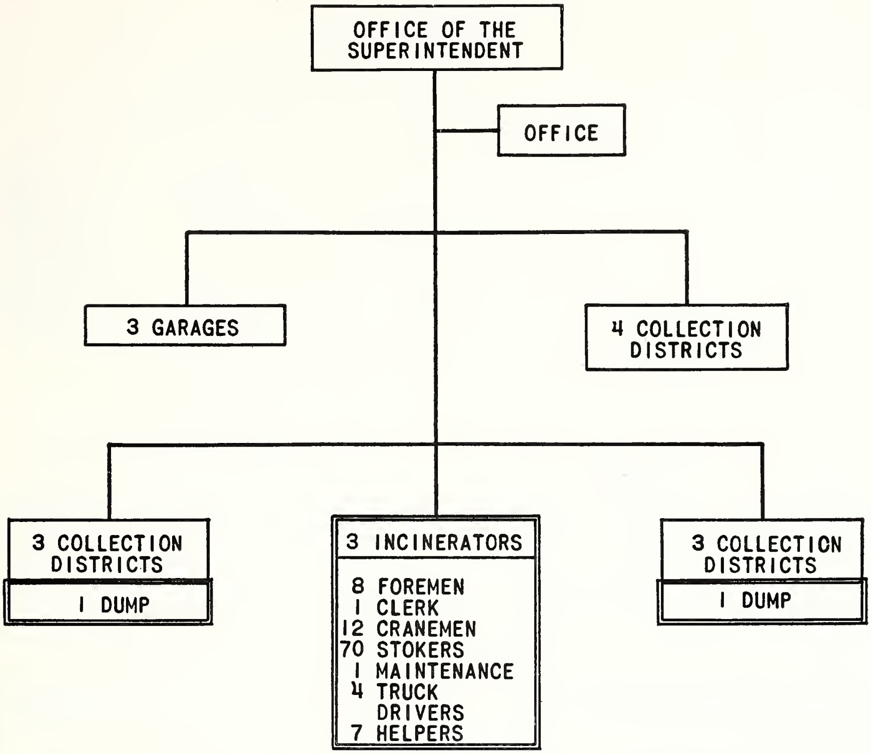

OFFICE OF THE SUPERINTENDENT
OFFICE
3 GARAGES
4 COLLECTION DISTRICTS
3 COLLECTION DISTRICTS
1 DUMP
3 INCINERATORS
8 FOREMEN
1 CLERK
12 CRANEMEN
70 STOKERS
1 MAINTENANCE
4 TRUCK DRIVERS
7 HELPERS
3 COLLECTION DISTRICTS
1 DUMP

Fig. 137. Organization chart, Division of Waste Collection, Department of Public Works, Cincinnati, Ohio.

two types of disposal methods. Some staff activities, including planning and research, are provided at the bureau level, whereas others, such as personnel and legal services, are provided either at the department level or for the city as a whole. Administrative services are provided at the bureau level, but equipment maintenance is in the division.

Cincinnati uses a similar top organization structure, but has some interesting differences, as shown in Figure 137. Refuse disposal is allocated to the division of waste collection in the department of public works. In each of two geographical areas, the responsibility for dumps and for refuse collection is under an area supervisor. A third area made up of four collection districts utilizes incineration, which constitutes the fourth operating unit of the division. No formal provisions for staff services are made at the division level. Those not performed by line officials are performed at the department level or for the entire city. Equipment maintenance and servicing are provided within the division but most staff services are provided at the department level.

In the Village of Winnetka, Illinois, refuse disposal is one of three

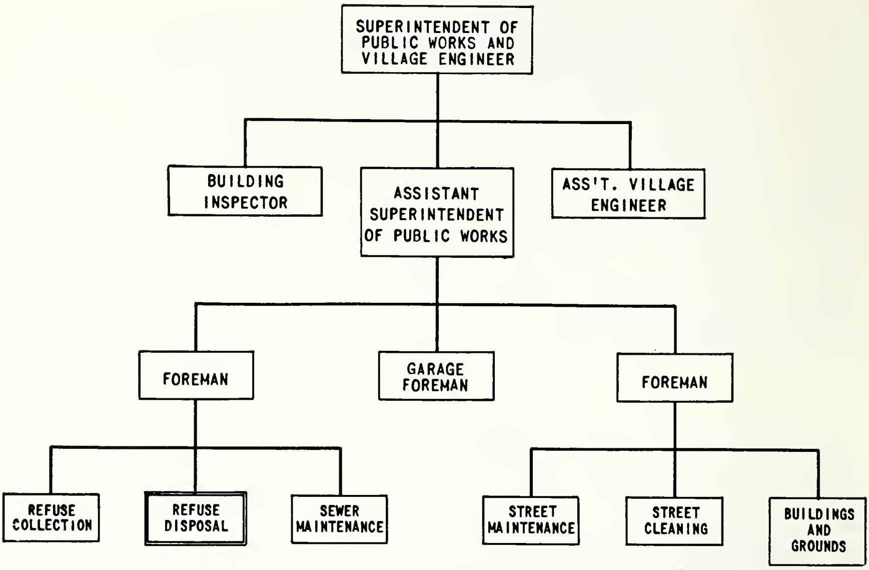

SUPERINTENDENT OF PUBLIC WORKS AND VILLAGE ENGINEER
BUILDING INSPECTOR
ASSISTANT SUPERINTENDENT OF PUBLIC WORKS
ASS'T. VILLAGE ENGINEER
FOREMAN
GARAGE FOREMAN
FOREMAN
REFUSE COLLECTION
REFUSE DISPOSAL
SEWER MAINTENANCE
STREET MAINTENANCE
STREET CLEANING
BUILDINGS AND GROUNDS

Fig. 138. Organization chart, Public Works Department, Winnetka, Illinois.

operations supervised by a public works foreman, as shown in Figure 138. Central services are provided at the village level except for equipment maintenance, which is a departmental responsibility.

The organization chart for New York (Figure 139) illustrates the allocation of the disposal function to a department of sanitation, a top administrative division of the city government. Other functions of the department are refuse collection, snow removal, and street cleaning. All operations, including plant maintenance and equipment services, are in a main operating unit made up of four bureaus, one of which is the bureau of waste disposal. This bureau in turn is divided by kinds of disposal method used into three divisions: incineration, landfill, and marine operations. Although some staff services are provided within the bureau of waste disposal, some units serve the whole operating unit. Engineering and other staff services are provided at the departmental level.

Disposal Authorities

A special government agency—an authority—is sometimes formed to handle refuse disposal responsibilities, particularly if several adjacent municipalities want to combine forces in a single disposal agency. The Southeastern Oakland County Garbage and Rubbish Authority, which operates an incinerator that serves 12 Detroit suburbs, and a Delaware County, Pennsylvania, authority, which services several Philadelphia suburbs, are examples.

The organization for an authority must be self-sufficient. It must include a governing body and provide staff services that in a department

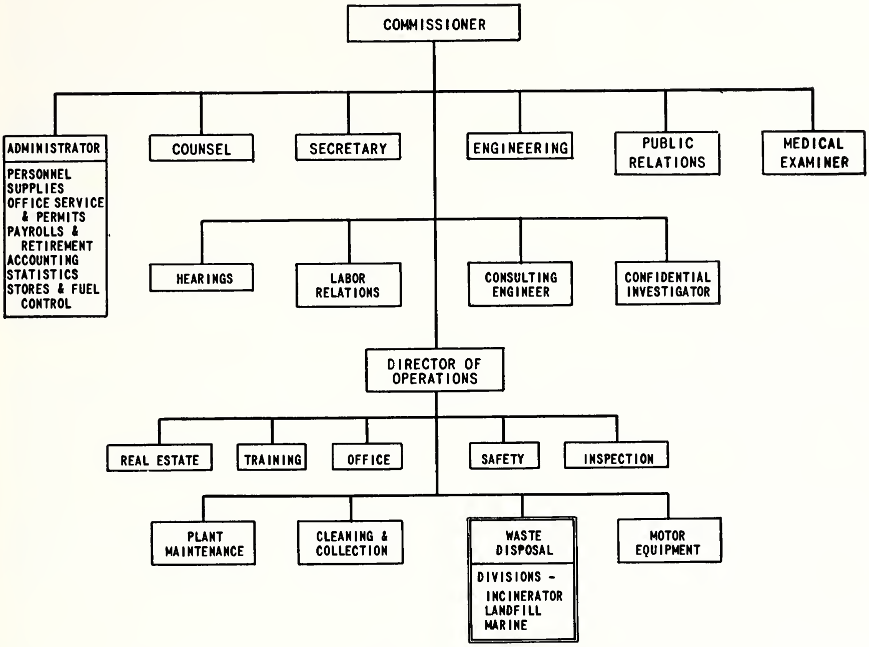

COMMISSIONER
ADMINISTRATOR
PERSONNEL
SUPPLIES
OFFICE SERVICE & PERMITS
PAYROLLS & RETIREMENT
ACCOUNTING
STATISTICS
STORES & FUEL CONTROL
COUNSEL
SECRETARY
ENGINEERING
PUBLIC RELATIONS
MEDICAL EXAMINER
HEARINGS
LABOR RELATIONS
CONSULTING ENGINEER
CONFIDENTIAL INVESTIGATOR
DIRECTOR OF OPERATIONS
REAL ESTATE
TRAINING
OFFICE
SAFETY
INSPECTION
PLANT MAINTENANCE
CLEANING & COLLECTION
WASTE DISPOSAL
DIVISIONS -
INCINERATOR
LANDFILL
MARINE
MOTOR EQUIPMENT

Fig. 139. Organization chart, Department of Sanitation, City of New York.

type organization are often furnished by municipal departments other than the sanitation or public works agency.

Personnel Administration

Sound personnel administration is important to the success of refuse disposal operations. Recruiting and keeping qualified, loyal workers and supervisors depend on fair dealings, adequate compensation, competent management, and good working conditions.

Since most cities have brought their personnel activities into a central administrative unit, the routine personnel activities of recruitment, classification, compensation, and retirement are not the direct and immediate concern of the management of refuse disposal operations. Therefore, this discussion deals mainly with those aspects of personnel administration that are of special importance to the disposal service and with the activities in which refuse disposal supervisors and employees participate.

Municipalities that have not centralized personnel administration place a much bigger burden on the operating units by requiring that they select and hire their employees and fix their compensation. This may be entirely satisfactory unless there is political involvement; but whenever personnel policies and decisions are subject to political pressures, the chance of having competent and efficient workers is greatly reduced.

Basic Standards

Good personnel administration requires the application of basic standards that will result in:

1. Attracting qualified persons to the refuse disposal service through a reputation for fair dealings, career opportunities, able management, and as favorable working conditions as are possible.
2. Providing remuneration that is equal at least to pay for similar work in private industry, taking into account the fact that work must sometimes be performed under unfavorable physical conditions.
3. Encouraging long service on a career basis through dependable, stable employment with opportunities for advancement and eventual retirement.
4. Guaranteeing equal opportunities for all qualified persons to compete for entrance and promotion under impartial and high standard examination procedures.
5. Training employees to do their work better and easier as a means to advancement.
6. Protecting employees from arbitrary separation from the service for trivial or personal reasons, but providing means of discharging incompetent and other undesirable employees for cause.

Routine Activities

All disposal agencies will have some personnel duties to perform. If the city has a central personnel department, the disposal division, bureau, or section is normally limited in its personnel functions to interviewing and accepting employees after they have been centrally certified, checking on competence during the probationary period, promoting morale, and keeping certain records. The operating department, however, often assists the central personnel agency in recruiting (particularly for technical positions), evaluating for promotions, and training. The central agency should establish personnel policies and standards and assist the operating agency in applying them. The operating agency's responsibility should normally be limited to applying the general policies and standards and making them effective. Good standards will be meaningless, however, if personnel policies are subject to political pressures; and if politics is a major factor the administrator should at least insist upon the right to discharge incompetent employees.

If a central personnel agency develops classification plans for employees of the refuse disposal service, disposal supervisors should be consulted in the process. Enough classes of positions should be provided to fit all of the kinds of work performed by the service, but the plan should provide some flexibility in utilizing employees on related work, particularly in preparation for advancement. Some municipalities put all incinerator personnel in one class to permit them to develop versatility in their operations. This, it is claimed, reduces the requirements for stand-by or relief personnel. However, the establishment of several classes makes it possible to utilize personnel in lower classifications as relief for higher classified personnel, thus providing an incentive for improvement and advancement and at the same time establishing an excellent in-service training opportunity.

Compensation elsewhere in the municipal service is normally higher than in the refuse disposal agency, but unusual conditions of the disposal service should be brought to the attention of the officials responsible for the compensation plan. For example, overtime work is not infrequent in some disposal operations and holiday employment may be common. Compensatory leave may be the answer, but usually an overtime pay provision should be incorporated in the pay plan. Furthermore, consideration must be given in the classification and compensation system to work under adverse conditions—dust, odor, and heat.

The personnel in charge of incinerators, landfills, and other facilities are key employees, and special attention should be given to their selection and training. These supervisors are responsible in large part for the efficiency of operations and their success depends upon technical, administrative, and leadership abilities.

Plant supervisors, in turn, should be allowed all possible latitude in selecting new employees for their operations. At the very least, they should interview eligible candidates and make recommendations on appointment to their supervisors or to the personnel agency.

In retirement plans, particular attention should be given to limitations on the useful span of service because of the kinds of tasks and the conditions of work involved.

Civil Service

Civil service systems are becoming increasingly common in municipal government because they offer advantages to both employees and employers. And more and more cities are including laborers jobs (of which there are many in refuse disposal facilities) in the civil service system, although the trend is more pronounced in cities of more than 100,000 population than it is in smaller ones.

Civil service provides security to good employees by establishing rules of employment and eliminating for the most part the political influence in the appointment and retention of employees that adversely affects the quality of government. A merit system of appointment and promotion provides for selection of employees on the basis of competitive examinations, which take into account training and experience. A positive program of personnel management also provides for equal pay for equal work through a classification and pay plan that includes pay ranges and pay increases for each job. Employees are usually rated by supervisors and are promoted or given pay increases on the bases of the rating and examinations. Most civil service systems provide for paid sick and annual leave and many include a retirement plan. These features make it easier for government agencies to recruit and retain well qualified employees than it was under the old political spoils system.

There are some disadvantages in the civil service systems of many municipalities that limit their usefulness, however. For example, when the system makes it difficult to discharge an incompetent, disloyal, or unproductive civil service employee, the quality of public service is lowered; also, some employees produce less than they would if unsatisfactory work was a cause for dismissal. The disadvantages of civil service may be reduced significantly, however, by recruiting as well qualified employees as possible and by dismissing unsatisfactory recruits during the initial probation period.

Training

Employee training has become an integral part of the personnel system of most cities. It is frequently provided by the sanitation or public works departments with assistance from the central personnel department. It may take the form of on-the-job instruction, formal class work within the city service, or classes in colleges or universities.

A good training program is rewarding not only to the employee but also to the city. The time spent by any employee in learning new procedures, methods, or techniques is usually more than compensated for by improved performance. The training of new employees before they actually start work is essential and may prevent costly blunders and wasted time.

The assignment of an incinerator superintendent to a plant during its construction is of inestimable value and should be done whenever possible. When operations start, he already knows the plant thoroughly, which increases his worth greatly. Similarly, an occasional visit of maintenance and operating employees to plants under construction is a good means of training them.

Municipalities should utilize training programs provided by universities and public administration organizations such as the American Public Works Association. Short courses on incinerator operation are available in some areas and can be developed further. Equipment manufacturing concerns provide training courses for users of their products. One large instrument manufacturer, for example, conducts instrument maintenance and repair courses for periods varying from two to five and one-half weeks at no charge to customers. Equipment and vehicle suppliers not only provide free start-up training sessions but frequently give periodic refresher training if requested.

In-service training is one of the most rewarding means of promoting morale and efficiency. This type of training can be conducted in sessions provided for particular groups or for individuals. At lower organizational levels, sessions are usually conducted during regular work hours without loss of pay to employees. For higher levels it may be advisable to conduct sessions in whole or in part outside of working hours. In-service training provides a means whereby labor and management can work together for the good of both the employees and the municipal service. In unionized operations it also makes for a better working relationship between unions and municipal governments.

Employee-Management Relations; Working Conditions

Good relations between the city administration, including the sanitation and refuse disposal supervisors, and the disposal employee require a thorough understanding on the part of both of the work that is involved, the conditions under which it is performed, and any special problems. Important among the many factors making for satisfactory employee-management relations are work incentives, employee facilities at disposal sites, employee suggestion systems, employee organization, recreation and social functions, and uniforms.

Work Incentives. Incentives in a refuse disposal operation are designed to raise the stature of the employment and to foster pride in membership in a merit organization. Morale also is built in the course of routine personnel activities through fair dealing in compensation, advancement, training, and career employment, including paid vacations, sick leave, and other fringe benefits. Good working conditions and employee participation in the improvement of disposal methods, procedures, and equipment also raise the level of operations. *Esprit de corps* can be developed by creating friendly competition among the crews of various facilities.

Emphasis on the public health aspects of refuse disposal also has proved a useful work incentive. Workers need to understand the difference between good and poor or inefficient disposal methods and the public benefit that results from sanitary operations. They can experience an intense satisfaction from simple improvements in procedures or methods if they are translated into terms of better public service and better health for the community.

An increasing number of public and private agencies are using incentive devices to maintain the interest of workers and to improve their performance. Among the incentives for outstanding service are:

1. Assignment to preferential shifts.
2. Assignment to preferential routing.
3. Provision of preferred equipment.
4. Letters of commendation from an administrative or elected official.
5. Money or other awards.
6. Safe driving emblems, cumulative by years.
7. Posting of photographs, other personal publicity.
8. Special time off, vacations, or leaves.
9. Dinners and banquets.

Employee Facilities at Disposal Sites. Improvements in the level of the refuse disposal service and in the caliber of refuse disposal employees have generated parallel improvements in working conditions, including facilities for personal sanitation and comfort. This advance is similar to that in industrial plants brought about through state labor laws, activities of employee organizations, and greater employer awareness of the importance of the health and well-being of workers to the quality of their performance.

Certain minimum facilities should be provided at any disposal site to which employees are regularly assigned: sanitary toilets, a supply of safe drinking water, and shelter for eating lunch and changing clothes.

New incinerators should and usually do have modern, sanitary, well-maintained toilet rooms, washrooms, showers, lunchrooms, locker rooms, and water coolers. Present-day standards call for two lockers or a double locker for each employee, one for work clothes and the other for street clothes. Other facilities should be adequate for the maximum number of employees on a shift and for equipment operators, truck drivers, and laborers on operations attached to the plant. Incineration plants that do not include appropriate facilities for personnel should be modernized.

Facilities for personnel at sanitary fill and dump sites are a special problem because of the temporary nature of the operations. Minimum facilities should be equivalent to those furnished on large construction projects, but permanent service buildings are possible only at the largest operations. At other sites, portable sheds or specially built trailers can be made to serve effectively for locker rooms, lunchrooms, and toilets.

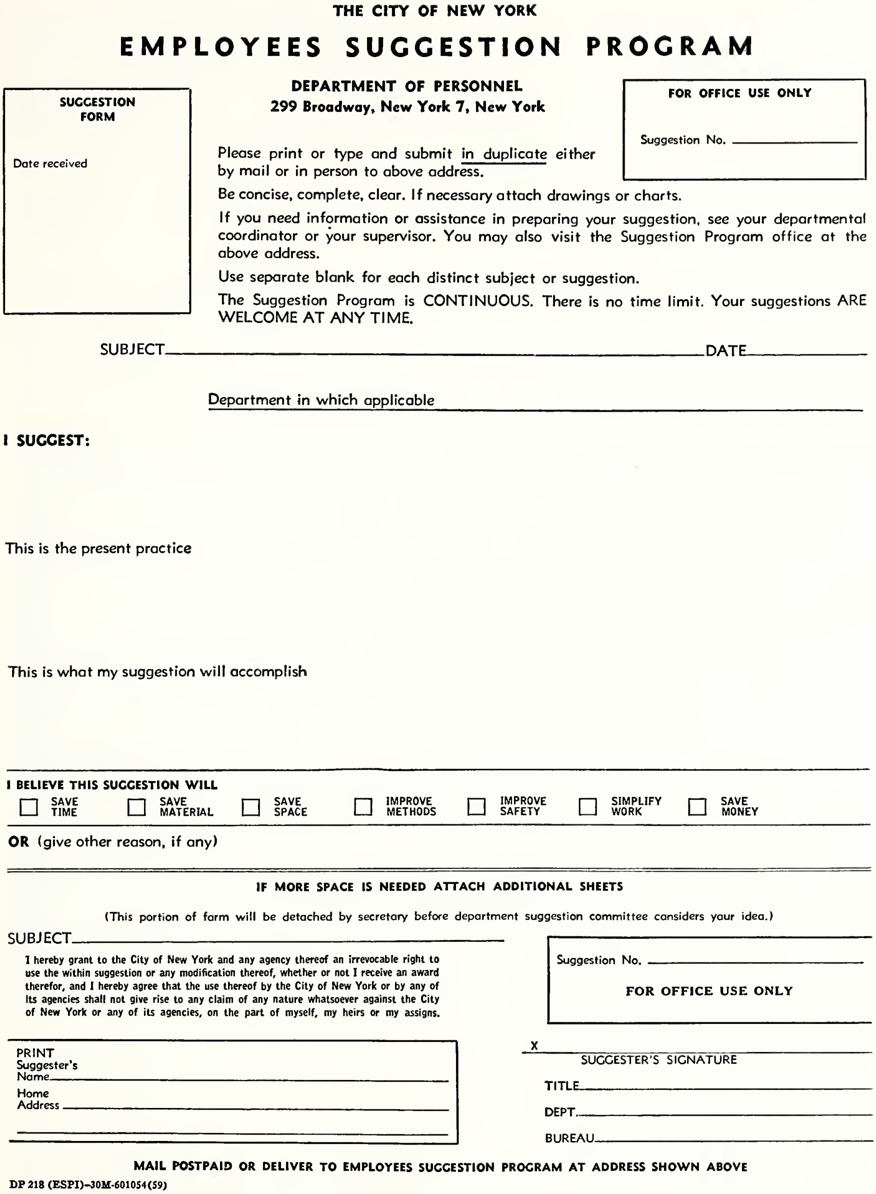
Suggestion Systems. One of the most fruitful means of securing worker participation in the improvement of refuse disposal services is through employee suggestion programs. An employee gets a genuine sense of belonging and of accomplishment from the adoption of his suggestions and public recognition of them.

A suggestion plan should encourage workers to submit ideas by making the submission as easy and free from embarrassment as possible. Each suggestion should be reviewed and evaluated and when judged valuable should be put into effect. Awards must be made carefully and publicized upon presentation.

Normally workers must be encouraged and even cajoled into making suggestions; the prospect of financial reward helps to overcome their reluctance. Usually a great deal of publicity is necessary to initiate such a program and to keep it alive, and announcements about it should be made at every opportunity in meetings and publications.

Suggestions must be made in writing, but this chore can be eased by the use of forms that indicate what information is required and provide places to enter it. Locked suggestion boxes should be placed at convenient locations, with a supply of suggestion forms nearby. Foremen and other supervisors should offer encouragement and should give assistance when asked. Some systems require that an idea be tried out and savings or benefits proved before the suggestion is put into writing for submission. Such restrictions eliminate many worthless ideas but may also prevent good ideas from being tried at all.

The review and evaluation of suggestions must be made impartially on the basis of careful analysis of potential benefits. Usually a committee of municipal officers and supervisors makes evaluations and recommends awards. The review must be thorough enough to identify suggestions that merit trial or testing, as well as to appraise those of proven merit. Specialists in refuse disposal should be on the committee or available



THE CITY OF NEW YORK

EMPLOYEES SUGGESTION PROGRAM

SUGGESTION FORM

Date received

DEPARTMENT OF PERSONNEL
299 Broadway, New York 7, New York

FOR OFFICE USE ONLY

Suggestion No. ________________

Please print or type and submit in duplicate either by mail or in person to above address.

Be concise, complete, clear. If necessary attach drawings or charts.

If you need information or assistance in preparing your suggestion, see your departmental coordinator or your supervisor. You may also visit the Suggestion Program office at the above address.

Use separate blank for each distinct subject or suggestion.

The Suggestion Program is CONTINUOUS. There is no time limit. Your suggestions ARE WELCOME AT ANY TIME.

SUBJECT______________________________ DATE__________

Department in which applicable ________________________

I SUGGEST:

This is the present practice

This is what my suggestion will accomplish

I BELIEVE THIS SUGGESTION WILL

☐ SAVE TIME ☐ SAVE MATERIAL ☐ SAVE SPACE ☐ IMPROVE METHODS ☐ IMPROVE SAFETY ☐ SIMPLIFY WORK ☐ SAVE MONEY

OR (give other reason, if any)

IF MORE SPACE IS NEEDED ATTACH ADDITIONAL SHEETS

(This portion of farm will be detached by secretary before department suggestion committee considers your idea.)

SUBJECT______________________________

I hereby grant to the City of New York and any agency thereof an irrevocable right to use the within suggestion or any modification thereof, whether or not I receive an award therefor, and I hereby agree that the use thereof by the City of New York or by any of its agencies shall not give rise to any claim of any nature whatsoever against the City of New York or any of its agencies, on the part of myself, my heirs or my assigns.

Suggestion No. ________________

FOR OFFICE USE ONLY

PRINT Suggester's Name________________________

Home Address ________________________

X________________________
SUGGESTER'S SIGNATURE

TITLE________________________

DEPT.________________________

BUREAU________________________

MAIL POSTPAID OR DELIVER TO EMPLOYEES SUGGESTION PROGRAM AT ADDRESS SHOWN ABOVE

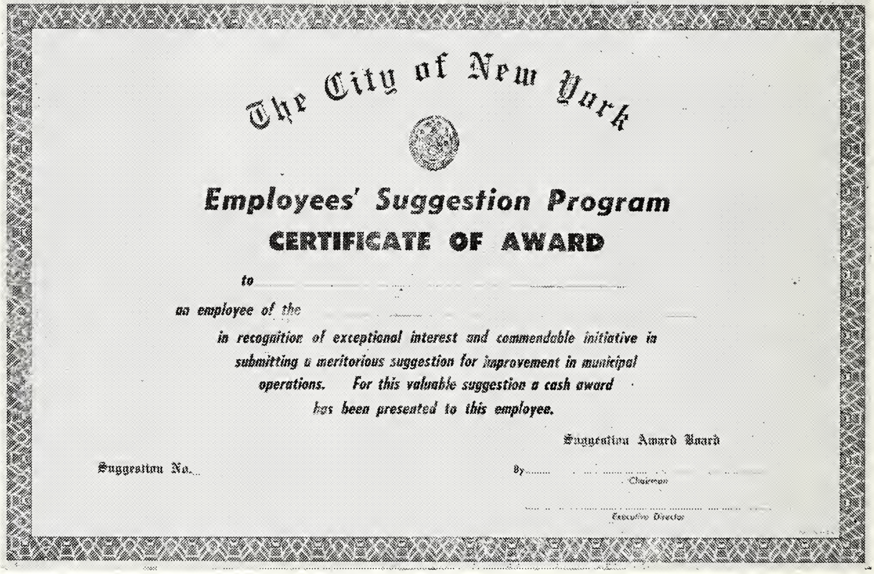
DP 218 (ESPI)–30M-601054(59)

Fig. 140. Form used by New York City to encourage submission of suggestions by employees. Anonymity of employee can be achieved by removing the perforated stub at the bottom before the filled-in form is sent for evaluation to the agency affected by the suggestion.

as advisers. Sometimes anonymity is secured by detaching the name of the suggestor as the first step in the review process and identifying the suggestion by number until a decision is made on its usefulness.

Refuse disposal supervisors should give all possible assistance to suggestors to try out their ideas before submission. The awards committee should also have authority to accept untried suggestions that in its discretion seem promising either for trial or for award without trial. In these decisions, the committee should have the full support and assistance of management.

An award can be cash, savings bonds, certificates of merit, or other recognition; its value should be consistent with the value of the suggestion. Sometimes cash is given in proportion to the probable savings, but obviously savings cannot be the sole basis of judgment. Awards consist of 10 per cent of one year's savings in Philadelphia, New York, and San Diego County. The District of Columbia established an incentive awards program in 1955 based on authority contained in the Government Employees' Incentive Awards Act of 1954 (see Section 14C of the District personnel manual).



The City of New York

Employees' Suggestion Program

CERTIFICATE OF AWARD

to ...

an employee of the ...

in recognition of exceptional interest and commendable initiative in submitting a meritorious suggestion for improvement in municipal operations. For this valuable suggestion a cash award has been presented to this employee.

Suggestion Award Board

Suggestion No. ...

By ...
Chairman

...
Executive Director

Fig. 141. Certificate issued by New York City to employee who makes an acceptable suggestion. The certificate is given at the same time that the employee is given a cash award.

Perhaps the most important part of a suggestion system is the acclaim given to award winners. Often awards are presented personally by the mayor or a department head at special functions or at regular assemblies of employees. The widest publicity should be given to such presentations.

Although many excellent ideas for improvement come from refuse disposal forces, the suggestion system cannot be considered a money-maker and should not be expected to be even self-supporting. Most programs cost much more than the value of the direct benefits of the suggestions. The real value comes from improved worker morale and the development of teamwork.

Organization of Employees. The right of employees of public jurisdictions to organize and bargain collectively is now generally recognized. Public works or sanitation employees may be affiliated with a national or local union. Their organizations may be formed on an industry basis and include all skills and services in a city department or they may include only a single craft.

Studies made by the APWA show that city employees in about half of the cities of more than 25,000 population have union organizations, but that city employees in only about a quarter of the cities of less than 25,000 population have such affiliations.

In one sense at least public employee organizations differ from those in private industry. Public opinion opposes strikes against governments because they threaten public safety and disrupt essential public health and other services, and this opinion is usually strong enough to prevent strikes by public employees. Good personnel practices are the accepted means through which governments can prevent strikes.

The principal purpose of most employee organizations is to provide an effective means of bringing grievances to the attention of management. Representatives of unions keep in close touch with administrative and supervisory employees and personnel agencies and often with legislative bodies. They are given hearings upon request and their advice is sought frequently; their interests relate to all aspects of public employment.

Properly established and operated grievance procedures are a valuable aid to effective management. City administrators and public works and sanitation officials should support the grievance procedure adopted sincerely and vigorously, doing their utmost to make it work and thus insuring employee confidence in it. Care also must be exercised to prevent undermining the authority of government officials to carry out their duties. Grievance policies and procedures must be based on the principle that management is the final arbiter of grievances, except in those cases where grievances reach the courts.

Grievances are seldom heard by refuse disposal agencies. Grievance procedures are usually administered by the department of public works or sanitation or on a city-wide basis. Refuse disposal officials and supervisors must do their part in developing and maintaining good employee-management relations; adjusting operations, conditions, and policies as needed; and helping management generate trust and confidence by hearing complaints before they become grievances and making reasonable corrections.

Recreation and Social Functions. It is a good policy to encourage occasional social functions for employees such as dinners and picnics and to develop athletic competitions such as bowling and softball. Some of these functions may be limited to refuse disposal personnel, while others such as athletic competitions may be on a department or city-wide basis. It is important to keep athletic activities within bounds in order to avoid interference with the efficiency of the operation, a condition that often occurs when "professionalism" develops.

Uniforms. A requirement that refuse disposal employees wear uniforms is generally recognized as aiding morale. A smart, practical uniform promotes neatness and cleanliness; it also results in savings for the employees in work clothes expense.

Uniforms may be furnished free or they may be purchased by the municipality and sold at cost to employees. Cities may launder the uniforms without charge whether they are provided by the city or by the workers, or they may require the employees to keep the uniforms clean. A usual requirement is two clean uniforms a week.

Accident Prevention

One of the fundamental rules of humanity is "to live and let live." It is also a generally accepted principle that no one shall injure or destroy life or property in the performance of his duties. Thus the basic motivations for an accident prevention program are humanitarian but economic considerations also are important.

It is generally conceded that accidents are a form of economic waste. The amount of money spent to settle claims for injuries or damages incurred in an accident is only one measure of economic loss. Other costs that must be borne by management overshadow direct accident settlement costs; they include repairs to vehicles or machines or the acquisition of new ones, interruptions of service, loss of the workers' services, loss of public good will, and costs of accident investigations, lawsuits, and court appearances.

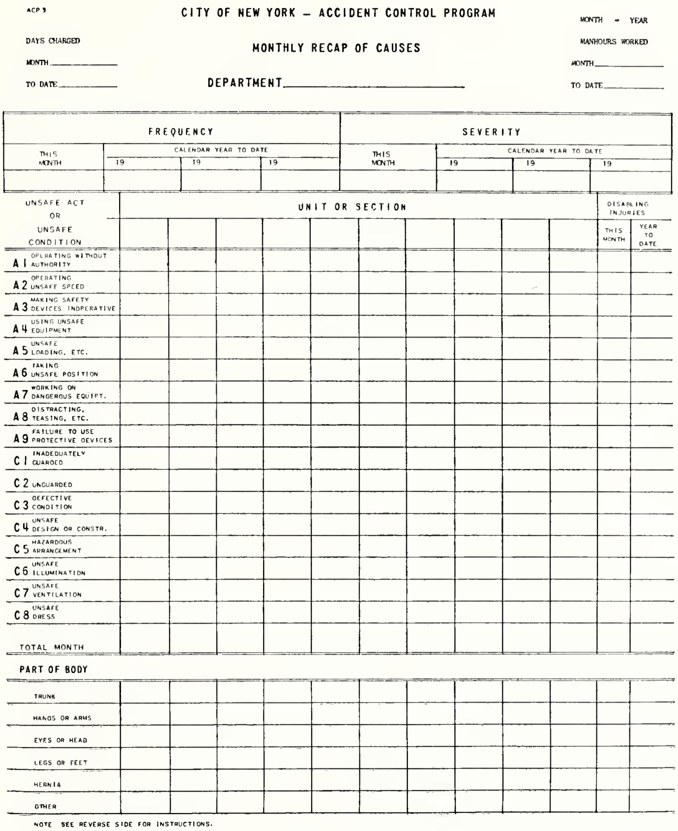
Safety training for public employees has proved fruitful; accidents have been reduced impressively in a number of cities. Truck driver, charger in an incinerator plant, and equipment operator are among the many occupations that can be made safer through training.

A safety program must be formalized to be effective. It requires:

1. The cooperation and full support of key personnel.
2. A competent staff of trained specialists for implementation of the program.
3. Complete analysis of accidents and accident records, and a systematic prevention plan emphasizing major causes first.
4. Meetings of operating heads.
5. Supervisor and employee education in accident prevention.
6. Maintaining interest through meetings and awards.
7. Development of safe-practice manuals for each major area of activity.

Records. The efficient management of any enterprise depends on proper control of men and materials; control in part depends on the use of records of personnel, equipment, and costs. Accident records are important in determining responsibility; they also provide data needed in disposal of claims and for supervision and control of workers. They are helpful in securing appropriations for prevention programs.

Accident records in themselves will not prevent accidents. They are valuable in prevention only if used to identify and determine conditions and practices that cause accidents, to maintain the interest of executives in accident prevention through appropriate reports, as a basis for a sound accident prevention program, and for the evaluation of rate and type of progress. Accident records must be accurate and comprehensive. They must reveal unsafe practices by workers and unsafe conditions of plants and facilities and suggest ways in which these practices and conditions can be corrected.



ACP 3

CITY OF NEW YORK – ACCIDENT CONTROL PROGRAM

MONTHLY RECAP OF CAUSES

DAYS CHARGED

MONTH __________

TO DATE __________

DEPARTMENT ____________________

MONTH - YEAR

MANHOURS WORKED

MONTH __________

TO DATE __________

FREQUENCY				SEVERITY			
THIS MONTH	CALENDAR YEAR TO DATE			THIS MONTH	CALENDAR YEAR TO DATE		
	19	19	19		19	19	19

UNSAFE ACT OR UNSAFE CONDITION	UNIT OR SECTION										DISABLING INJURIES	
											THIS MONTH	YEAR TO DATE
A 1 OPERATING WITHOUT AUTHORITY												
A 2 OPERATING UNSAFE SPEED												
A 3 MAKING SAFETY DEVICES INOPERATIVE												
A 4 USING UNSAFE EQUIPMENT												
A 5 UNSAFE LOADING, ETC.												
A 6 TAKING UNSAFE POSITION												
A 7 WORKING ON DANGEROUS EQUIPT.												
A 8 DISTRACTING, TEASING, ETC.												
A 9 FAILURE TO USE PROTECTIVE DEVICES												
C 1 INADEQUATELY GUARDED												
C 2 UNGUARDED												
C 3 DEFECTIVE CONDITION												
C 4 UNSAFE DESIGN OR CONSTR.												
C 5 HAZARDOUS ARRANGEMENT												
C 6 UNSAFE ILLUMINATION												
C 7 UNSAFE VENTILATION												
C 8 UNSAFE DRESS												
TOTAL MONTH												
PART OF BODY												
TRUNK												
HANDS OR ARMS												
EYES OR HEAD												
LEGS OR FEET												
HERNIA												
OTHER												

NOTE SEE REVERSE SIDE FOR INSTRUCTIONS.

Fig. 142. Form used in New York City for monthly report on accidents. Such reports pinpoint unusual conditions that alert management to the need for corrective steps.

Program Activity. Activities directed to insuring maximum safety may include supervisor and employee meetings on accident prevention, supervisor and employee participation in safety committee work, and the showing of films or slides covering appropriate subject matter. A series of educational talks on accident prevention keyed to prime accident causes, limited to approximately 15 minutes, and given by competent accident prevention specialists, arouses and maintains supervisor and employee interest, brings the accident prevention message to the men directly concerned, and develops employee interest in further investigation, thus creating a pool of "on the spot" safety advocates.

Safety Manuals. It is accepted throughout industry that an employee should be provided with printed matter in easily understood language that describes how he should perform his work efficiently and safely. A manual outlining safety practices should be developed as a part of the accident prevention program in refuse disposal operations so that the men will have definite guides for safe operating practices.

Protective Clothing and Equipment. Protective clothing and equipment should be provided for comfort and must be provided for the safety of refuse disposal employees. Federal labor laws and some state laws set safety standards for certain workers, but they are usually minimal and meet only a part of the needs.

Incinerator employees who are subjected to dust, heat, and smoke must have goggles, shields, or masks, as required; maintenance workers should wear helmets; and charging floor attendants must have safety belts if operating conditions warrant. Personal safety equipment is usually provided by the city without charge to employees.

Employees at sanitary fills, dumps, or other outside disposal facilities who work in all kinds of weather should be protected from rain, snow, cold, and heat to the degree possible. Sometimes cities provide raincoats, boots, and rain hats to make sure that workers have them when needed.

In addition to protective clothing, protective equipment and devices must be provided for the safety of employees. Basic precautions must be taken to protect men who operate machines and prime mover and power transmission devices. Safety equipment includes mechanical feeding devices, remote control operating mechanisms, and dust and fume controls. Processes and procedures should be reviewed to insure that as many hazards as possible are eliminated before installing personal protective equipment (summarized in Table 38).

Studies of accident data have led to the development of personal safety equipment specifically designed to protect against known hazards. Workers required to wear such equipment must understand its uses and limitations. The ease and comfort with which it can be worn and its noninterference with normal work procedures are prime considerations in selecting such equipment.

Wages and Hours

Compensation for employees at refuse disposal facilities is usually equivalent to that paid in private industry for work of similar skills and hazards. Some municipalities have a standard work week with standard

TABLE 38

EQUIPMENT USED TO PROTECT EMPLOYEES AT REFUSE DISPOSAL FACILITIES

Head (including hair and ears)	Skull guard (hard hat)
Face and eyes	Hood Goggles Face shield Welding helmet
Respiratory system	Oxygen breathing apparatus Air respirator Canister and cartridge respirator Filter respirator
Hands and feet	Gloves and hand leathers Safety shoes Foot guards
Body	Chemical resistant clothing Heat resistant clothing Cold resistant clothing Water resistant clothing Radioactive resistant clothing Special purpose equipment: Life line Life ring Reflector belt

pay for it for such employees, and time worked beyond the standard week is usually paid for as overtime. Most cities pay workers in refuse disposal facilities on an annual salary basis and give paid vacations and sick leave. Others, however, pay workers on an hourly basis. Employees who work other than day shifts at disposal facilities are paid higher rates than those on the day shift to compensate for the less favorable working hours.

A survey of compensation to incineration plant personnel of 12 major cities, made in 1959 by the American Public Works Association, is summarized in Table 39. The range in annual pay for selected positions is:

	From	*To*
Superintendent	$5,280	$9,944
Foreman	4,204	9,174
Fireman	3,347	6,000
Crane operator	3,420	8,142
Truck driver	3,420	5,457
Laborer	2,320	5,355

Four cities reported overtime payments for one job ranging from $145 to $1,350 annually. One city allowed compensatory time off for overtime work.

TABLE 39

ANNUAL SALARIES FOR EMPLOYEES AT MUNICIPAL INCINERATION PLANTS IN 12 CITIES, 1959, BY POSITION[1]

City	*Superintendent*	*Foreman*	*Fireman*	*Crane Operator*	*Truck Driver*	*Laborer*
Buffalo			$4,150	$5,050		
Chicago	$9,944	$9,174[2]	6,000[3]	8,142		$5,310[4]
Cincinnati[5]	6,567-7,100	5,236-5,769		5,103-5,369	$4,167-4,435	3,763-4,032
Detroit[6]		5,221-5,450	4,866-4,971	4,930-5,096	5,054	4,410-4,514
District of Columbia[7]		5,158	4,264	4,804	3,759	3,723
Houston		5,280		5,152		2,320-3,706
Los Angeles[8]		5,868-7,296	4,500-5,868	4,500-5,868		4,044-5,280
Milwaukee	8,195-9,258[9]	6,151-6,132	4,938-5,376	5,515-6,006	4,808-5,212	4,433-4,835
Minneapolis		7,092	5,451	6,014	5,457	5,355
New York [10]	8,565 (1.0)	7,500 (1.5)	5,500 (1.5)	9,500 (2.0)	4,050-5,350 (1.5)	
Philadelphia [11]	5,280-6,632	4,204-4,820	3,347-3,838	4,605-5,280	3,665-4,204	2,919-3,502
St. Louis		4,813-5,849	3,420-4,157	3,420-4,157	3,420-4,152	3,258-3,960[12]

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[1] American Public Works Association survey.

[2] Electrical-mechanical.

[3] $24 per day.

[4] $21.25 per day.

[5] $2 and $4 per week bonus paid to 2nd and 3rd shift employees respectively (except superintendent).

[6] $4 per week bonus paid to 2nd and 3rd shift employees. Annual overtime pay: $325 to $390 per position.

[7] 10 per cent higher for night shift.

[8] Overtime ranges from $145 to $240 per year per position.

[9] Supervises 3 plants. Overtime for other positions ranges from $689 to $1,262 per year.

[10] Equivalent time off at rate shown in parentheses.

[11] All salaries raised 6 per cent in 1960; all except superintendent and foreman receive overtime ranging from $885 to $1,350 per year.

[12] Called refuse collector.

Fiscal Management of Disposal Operations

Reporting and analyzing information on refuse disposal operations are important to good management. Many of the major decisions in planning, providing new facilities or additions to old ones, scheduling activities, staffing, and financing depend in large measure on regular, complete, and accurate data on performance and costs. Meaningful budgeting depends on reliable forecasts, specific work programs, and accurate information on costs.

Fortunately, refuse disposal operations lend themselves readily to quantity determinations, simple reporting, and analysis. The processes involve measuring performance and costs, reporting on operations, summarizing and analyzing the data regularly, and making the results known promptly to supervisors and management.

Measurement of Performance

Unit cost and performance determinations require basic measurements of work accomplished. The usual measures are volume (cubic yards) or weight (tons) of the refuse received for disposal.

Most municipalities have used volumetric measurements in the past and for the most part these measurements have been unreliable and misleading. Determinations of volume should be made while the refuse is on the collection truck and each truckload should be examined to determine the degree of compaction, general nature of the material, and percentage of the truck body volume that is occupied. In practice these refinements are seldom incorporated into the volume recorded. Partial loads are often indiscriminately reported as full loads and approximations are used that result in inaccurate reporting.

Volumetric information is necessary, however, for making certain decisions. Since the life of a landfill site is determined by its volumetric capacity, it is important to keep volume records and utilize accurate compaction computations to determine it. This information is essential to sound planning. Periodic surveys of actual fill volume will provide not only firsthand information on future capacity but also an accurate means of checking truck volume records. If refuse is measured by weight, sample loads should be analyzed to determine volume as well. A density factor for converting tons to cubic yards is necessary for this purpose.

Weight measurement provides much more realistic and accurate refuse disposal data and is the only measure of quantity that is sufficiently exact for performance reporting. A ton is the normal unit used for measuring refuse. Scales must be provided to weigh all refuse if this measure is adopted. Inasmuch as scales are almost always provided at incineration and other plants, and even at large landfills, weight determinations are no problem at such places. Most cities do not provide scales at small fills or at dumps, however, because of the expense of installation and operation. Some recent developments, including portable scales and others that although not actually portable can be moved easily from one location to another, give promise of overcoming the most serious objections to weighing at landfills.

The trend is toward weight measurement of all refuse and some cities have already achieved this goal. New York, for instance, is now weighing all of the refuse taken to all of its disposal facilities (incinerators, marine transfer stations, and landfills). Weighing is done semi-automatically on 25 electronic scales that print net payloads and nine other items of information. The use of self-printing truck scales provides a continuous record of production, including the weight of each truck load by truck number and time of delivery. The recording mechanism can be located some distance from the scale platform.

Truck scales are expensive to purchase, install, and operate, and the self-printing type costs more initially and requires slightly more maintenance than the manual or indicating type. Weight records, to be useful, must be kept continuously, which requires rapid repairs or the provision of stand-by scales in case of breakdown. Consequently, a reasonable number of spare parts should be kept on hand. The type of scales and the number needed should be determined on the basis of records of breakdowns and the availability of parts. It may be desirable to contract for scale maintenance.

Maintenance of scales is important; the cost of neglect is high. Normal maintenance requirements of modern scales are low unless the scales are tampered with or abused. Maximum protection against tampering should be provided for all installations.

Field Reporting

Field reports of refuse disposal operations constitute the initial and most important phase of the performance and cost analysis process. Management analyses and reports can be no more complete and accurate than the field data prepared by disposal workers and supervisors on which they are based.

The amount of refuse received and disposed of and other needed information is reported automatically if self-printing scales are used; if manual scales are used, care must be used to record gross, tare, and net weight, truck number, and time. If scales are not used, the volume must be estimated as accurately as possible. Complete records should be prepared at each refuse disposal facility.

Incinerator operating reports should show all pertinent data for each shift of personnel on duty, hours of work, furnaces operated, fuel used, breakdowns, maintenance work, and quantities of refuse received and ash removed. Reports on sanitary landfills may be simpler, but should include information as to location, personnel on duty, hours of work, weather, and amount of refuse and cover material placed.

All field reports should be made daily and forwarded to superiors at the end of the day or the beginning of the following day.

Performance Records

Refuse disposal supervisors depend more and more on performance records and analyses in operational control. The analyses require only simple calculations, so the supervisor of a disposal facility should have complete performance data promptly.

Performance units for refuse disposal usually are man-hours per ton of refuse disposed of or tons per hour of operation. Cubic yards instead of tons must be used at facilities without scales. All the data needed for performance records, such as man-hours, amount of refuse, and operating hours, must be included in the daily reports, which should be summarized for district, area, division, bureau, and department officials. Reports also should be summarized weekly, monthly, and annually to give a continuous appraisal of operations and to provide the means of discovering weak points in the operation.

In summary, the establishment of performance measures as a means of controlling operations depends on:

1. A reporting system that includes all personnel, materials, and equipment used.
2. Report forms that are simple but comprehensive.
3. Prompt and accurate reporting.
4. Prompt and accurate analysis and evaluation of data.
5. The presentation of data and evaluations in a simple, easily understood, and useful manner.

The use of charts, graphs, tables, and figures can aid in the presentation of much of the information.

Cost Accounting

Unit costs have been the principal basis of refuse disposal control for many years. Reliable cost data, carefully interpreted and used, are still important to management—second only to performance measurement. One difficulty with using unit costs to measure performance effectiveness, however, is that the information is usually available so late that it is valueless for day-to-day or week-to-week control. Unit cost reports are usually prepared monthly and are not available until about 10 days after the close of a month's business and often much later.

Another shortcoming of unit costs as a measure of efficiency is the lack of agreement among cities on what elements of cost should be included. For example, most cities report incineration costs that reflect only direct operating costs—labor, materials, and utilities such as electricity and gas. Occasionally water is included if it is used in large quantities. Fixed capital costs of the plant are usually ignored. Sometimes an item is included for amortization of that portion of a new facility that was financed by a long-term loan. Final disposal of incinerator residue is often not reported at all. Equipment expense is sometimes omitted. Office and other kinds of overhead are another variable that is sometimes included to show a portion of the cost of direct administration and supervision up through the bureau head, but more often overhead is ignored. Because of these variations, valid comparisons of unit costs among cities are usually impossible; comparisons of dissimilar data are seriously misleading.

TABLE 40

DEPARTMENTAL COSTS OF INCINERATION AND LANDFILL OPERATIONS BY AMOUNTS OF REFUSE RECEIVED AND PROCESSED, NEW YORK CITY, JANUARY-JUNE, 1960[1]

	Incineration[2] *(853,164 Tons Received; 656,808 Tons Processed)*			*Landfills (875,162 Tons Received and Processed)*	
	Amount	*Cost per Ton Received*	*Cost per Ton Processed*	*Amount*	*Cost per Ton Received and Processed*
Bureau personnel					
Direct labor	$1,658,307	$1.943	$2.524	$ 363,185	$0.414
Servicing vehicles, plant security, and housekeeping	449,361	0.526	0.684	97,780	0.111
Local supervision	215,516	0.252	0.328	66,260	0.075
Division administration	46,322	0.054	0.070	40,720	0.046
Bureau administration	45,691	0.053	0.069	10,904	0.012
Paid absences	483,032	0.566	0.735	117,351	0.134
Total, Bureau personnel	2,898,229	3.397	4.412	696,200	0.795
Operating supplies					
Gas, oil, and grease	12,278	0.014	0.018	24,552	0.028
Fuel and other	29,540	0.034	0.045	21,034	0.024
Service and repair materials	73,309	0.085	0.111	8,505	0.009
Department overhead					
Motor vehicle maintenance	79,726	0.093	0.121	196,541	0.224
Plant and equipment maintenance	198,687	0.232	0.302	25,063	0.028
General administration	180,722	0.211	0.275	43,029	0.049
Total	$3,472,491	$4.070	$5.286	$1,014,924	$1.159

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[1] Departmental costs do not include amortization, utilities, and fringe benefits.

[2] Costs include residue hauling only; residue disposal included in landfills.

Within a single jurisdiction in which the same cost elements are included in each statement, unit costs can be useful in operational control and management. If adequately reported, such costs constitute an overall measure of the amounts spent for manpower, equipment, materials, utilities, and overhead. The total cost per ton disposed of is a useful and reliable measure of long-term efficiency, and each refuse disposal agency should develop and use unit costs for continuing analysis of operating efficiency. Tables 40 and 41 illustrate how these factors are included in New York's reporting system.

A standard reporting system for refuse disposal operations that includes fixed and final costs is desirable. The following elements of cost can be standardized:

1. Amortization of capital investment, including equipment replacement and major alterations and repairs.
2. Direct operations (personnel).
3. Tools, supplies, and utilities.
4. Routine maintenance and repairs.
5. Administration and overhead.
6. Reclamation and salvage revenues (credit).

In working out the amortization of plant and major equipment costs, the basis should be the tonnage that can be processed in a 24-hour-day operation and the amortization should be spread over periods from 15 to 40 years, depending on the parts of the plant involved. On a 25-year life basis, assuming a unit costing $1,000 per ton per day of estimated or rated capacity, 4 per cent interest, 80 per cent use of capacity (a conservative figure for a 25-year life), and 24-hour operation for 250 days a year, the amortized cost of a plant on a tonnage processed basis (using straight line depreciation) would be 30 cents a ton. The amortized cost per ton of a plant that costs $5,000 a ton to construct would be five times 30 cents, or $1.50 per ton of refuse processed. If experience indicates a change in the number of tons of refuse processed from that estimated, corrections are required in the amortization computation.

Operating Personnel. Costs for operating personnel should include those for all personnel involved: (1) all clerical help used in keeping plant records; (2) personnel used in the weighing, tipping, and furnace charging areas; (3) men used to charge, operate, stoke, fire, and tend the furnaces; (4) personnel used for loading and transporting incinerator residue to a final disposal site; (5) plant cleaning and first echelon maintenance personnel, including all persons involved in plant sanitation, the cleaning of bins, furnaces, flues, and so forth, and those who perform daily and weekly maintenance operations, such as partial replacement of grates and links, small areas of refractory surfaces, stoking tools, and piping; and (6) all plant supervisory personnel.

If the plant is equipped with devices such as waste heat boilers and fly ash eliminators that require employees not covered in the categories above, their costs of operating should be added. To these direct costs should also be added overhead, including insurance, vacations, sick leave,

TABLE 41

SUMMARY OF PRINCIPAL OPERATING AND COST DATA FOR 10 INCINERATION PLANTS, NEW YORK CITY, JUNE, 1960

Total refuse received	
Truck loads	49,290
Tons	147,649
Residue produced (adjusted to dry weight)	
Total tons of residue	38,386
Net tons destroyed	109,263
Per cent of tons received	74.0
Plant performance	
Total tons per day design capacity	7,410
Per cent of design capacity	75.5
Per cent furnace up-time	85.3
Per cent furnace performance	88.5
Total plant payroll unit costs	
Per ton received	$3.16
Per ton destroyed	$4.27
Direct operating man-days per ton received	.076
Total man-days per ton received	.105
Operating man-days, by function	
Receipt of refuse	1,351
Loading furnaces	
Crane operations	1,401
Hopper tending	1,231
Burning	4,243
Oiling	476
Residue handling	1,153
Subtotal operating man-days	9,855
Residue trucking	1,425
Total operating man-days	11,280
Supervision and service man-days, by function	
Plant supervision	1,506
Cleaning related to burning	402
Vehicle oiling and greasing	183
Plant servicing and repairs	1,218
Heat and power plant operation	231
Security and housekeeping	724
Total man-days for supervision services	3,264
Total plant operating man-days	15,544

pensions, and all other employee fringe benefits. In the absence of exact data on the cost of fringe benefits, an allowance of 15 to 20 per cent of direct costs is usually adequate.

The breakdown of personnel operating costs decribed may be difficult to compute in small plants where employees frequently perform several of the functions noted. In such instances, it may be simpler and equally satisfactory to consolidate some of these costs, provided that the consolidation is clearly recognized.

Tools, Supplies, and Utilities. Costs for tools, supplies and utilities include everything used in operating the plant—among others, light bulbs, weight tickets, refractory patching material, stoking tools, brooms, crane parts, fuel, power, and water. The costs involved in purchasing supplies should be included under administration and overhead and should include an allowance for warehousing and transporting materials.

Routine Maintenance and Repairs. Costs for maintenance and repairs should be included in the expense budget and should be dealt with in the same way as personnel and other expenses. However, major alterations, plant rehabilitation, and equipment replacement items that require amortization should be included in the capital budget. Included in the capital budget category are reconstruction of furnaces, flues, and combustion chambers; structural changes to the building; extensive chimney repairs.

Administration and Overhead. Costs for administration and overhead, which include all those for employees outside of the plant operation (engineers, analysts, secretaries, clerks) and for rent and insurance, for instance, should be prorated to the various operations.

Revenue received from the sale of steam from waste heat or salvage should be considered as a credit. Charges for administrative and operating costs related to salvage or reclamation should be taken into account in computing net revenue.

A detailed breakdown of incinerator operating costs for New York is given in Table 42. The city's plants are divided into two groups: the first composed of five mechanically-stoked, continuous-feed type plants; the second composed of four manually-stoked, batch-feed type plants. All plants process the same kinds of mixed refuse, including noncombustibles, with the exception of ashes and bulky materials. They operate 24 hours a day, 5½ days a week at an average of 80 to 85 per cent of design capacity.

The factors described above that are used in determining incineration costs also are used, with appropriate modifications, to determine sanitary landfill operating costs. Amortization of capital costs, for example, is applied to site preparation and automotive equipment costs. The costs of land acquisition must also be taken into account, but they may be a net credit because of the appreciating value of the property as a result of the filling operation.

Per capita landfill costs based on a 1959 survey of more than 200 sanitary landfill operations throughout the United States are summarized

TABLE 42

UNIT COSTS OF INCINERATION OPERATION IN NEW YORK CITY, JANUARY-JUNE, 1960
(Per ton of refuse destroyed)

	Mechanically Stoked Continuous-Feed (5 Plants)	*Manually Stoked Batch-Feed (4 Plants)*
Personnel		
Overhead and administration[1]	$0.33	$0.65
Operating labor[2]	2.93	5.82
Maintenance labor[3]	0.17	0.35
Fringe benefits	0.97	1.68
Motor vehicle maintenance	0.11[4]	0.14[4]
Utilities	0.10	0.10
Materials and supplies	0.12	0.14
Capital amortization	0.95	0.65
Residue disposal[5]		
Hauling	0.28	0.34
Landfilling	0.71	0.86
Total cost per ton	$6.67	$10.73
Tons of refuse destroyed[6]	444,100	212,709

[1] Engineering and central administration costs, excluding direct plant administration costs.

[2] All personnel on plant payroll, excluding residue truck drivers but including supervision, clerical help, and full-time maintenance employees.

[3] All personnel not on regular plant payroll who do maintenance work periodically.

[4] Includes labor, materials, and administration.

[5] Costs computed on basis of tons of incoming refuse.

[6] Includes all refuse except ashes.

in Figure 143. As in incineration, reports of sanitary fill costs vary with the size of operation, number of shifts per day or week, and the accuracy of the reporting.

Budget Control

Modern budget control is another essential tool of mangement. The purposes of budgeting are to assure that suitable plans for development and operation are made, that adopted policies are carried out, and that spending is held within the amount budgeted for the various purposes.

The first step in budget preparation is forecasting the amount of each kind of work to be done during the coming budget year. Forecasts should be based on long- and short-range plans for development of facilities, on plans of operation, and on past operating records. Plans for expanded activities and new operations must be given special attention.

The second step of budget preparation is the development of work programs. The forecasted amount of work is translated into dollars by correlating work standards and unit costs. A work program should indi-

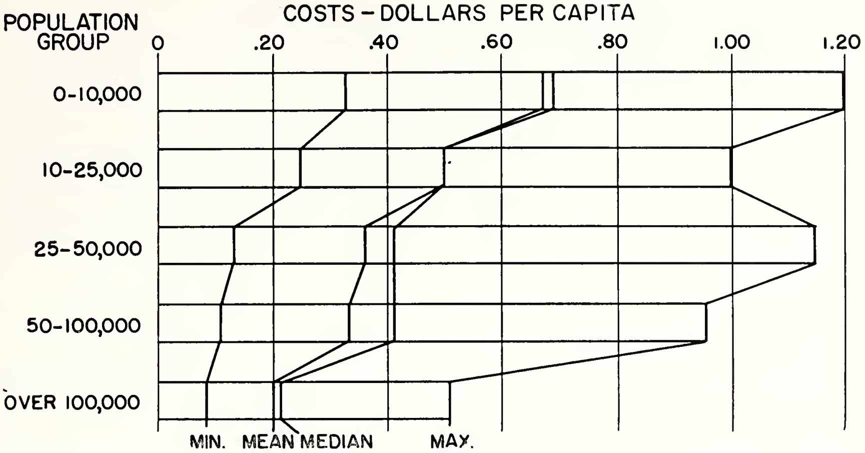


Fig. 143. Per capita costs of sanitary landfill operations in more than 200 cities and towns in 1959. Data collected by the APWA.

cate by months or quarters what work is to be accomplished and how much it will cost.

After the budget is adopted, the work program must be revised to fit the amount of money available. The revised program becomes the year's plan of operation, both as to spending and as to the amount of work to be done for the amount budgeted. Budget appropriations are frequently allotted on a quarterly basis for control purposes.

Inasmuch as the budget is the official plan of control, regular statements of cost and performance should be based on it. Sometimes current spending and performance are compared with those forecast for a year ahead to show the status of the programs. If budgets do not include amortization of capital expenditures and major plant maintenance, the budgetary control statements should not include such expenses. Budget statements that omit amortization figures may be adequate for operational analysis and control, since the costs represent valid amounts for internal comparisons among plants, crews, methods, and for most other operating purposes. The omission from such statements of amortization costs should not be overlooked, however, in making comparisons among various methods or with other jurisidictions. The unit amortization cost of capital outlays should be recorded for use when total unit costs are needed.

Purchasing

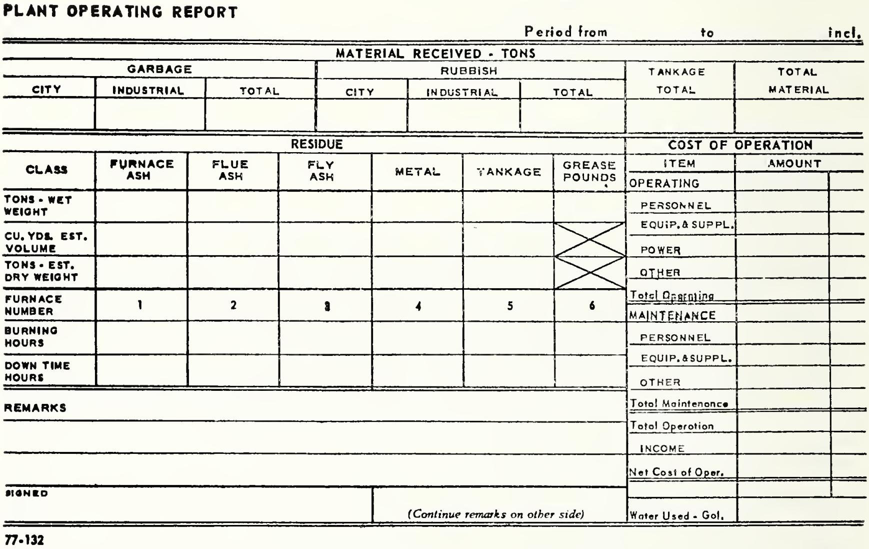
Refuse disposal does not require extensive use of materials, so purchasing is not a major management problem. Equipment, parts, supplies, fuel, and lubricants are usually procured through a central services office or agency for the city. Large municipal refuse disposal agencies may have the authority to make direct purchases under certain conditions and in accordance with prescribed procedures, however.

Under a central purchasing arrangement, the head of the disposal agency and his authorized representatives usually issue requisitions for the supplies and equipment required. Items that are in stock are issued to the refuse disposal agency and charged to the appropriate accounts; items that are not in stock are procured by the purchasing agent.

Good practice requires that the city finance office review purchase orders for encumbrance of appropriations or allotments in order to keep budgetary control. Blanket and emergency purchases must be controlled if the budget is not to be exceeded.

Analysis of Performance and Costs

Accurate records and analysis of performance data are important in a refuse disposal operation, whether it is large or small. If it is large, a detailed system and the use of mechanical aids are essential; if it is small, the analysis can be simple. The collecting, sorting, and summarizing of data can be simplified if well designed forms and well planned reports are used. A form for reporting operations at an incineration plant in Philadelphia is shown in Figure 144. Figure 145 is a similar form used in Edmonton, Alberta, Canada, for monthly reports. A performance record and man-hour correlation recording and computation form is shown in Figure 146.



PLANT OPERATING REPORT

Period from to incl.

MATERIAL RECEIVED - TONS

GARBAGE			RUBBISH			TANKAGE	TOTAL
CITY	INDUSTRIAL	TOTAL	CITY	INDUSTRIAL	TOTAL	TOTAL	MATERIAL

RESIDUE

CLASS	FURNACE ASH	FLUE ASH	FLY ASH	METAL	TANKAGE	GREASE POUNDS
TONS - WET WEIGHT						
CU. YDS. EST. VOLUME						☒
TONS - EST. DRY WEIGHT						☒
FURNACE NUMBER	1	2	3	4	5	6
BURNING HOURS						
DOWN TIME HOURS						

COST OF OPERATION

ITEM	AMOUNT	
OPERATING		
PERSONNEL		
EQUIP. & SUPPL.		
POWER		
OTHER		
Total Operating		
MAINTENANCE		
PERSONNEL		
EQUIP. & SUPPL.		
OTHER		
Total Maintenance		
Total Operation		
INCOME		
Net Cost of Oper.		
Water Used - Gal.		

REMARKS

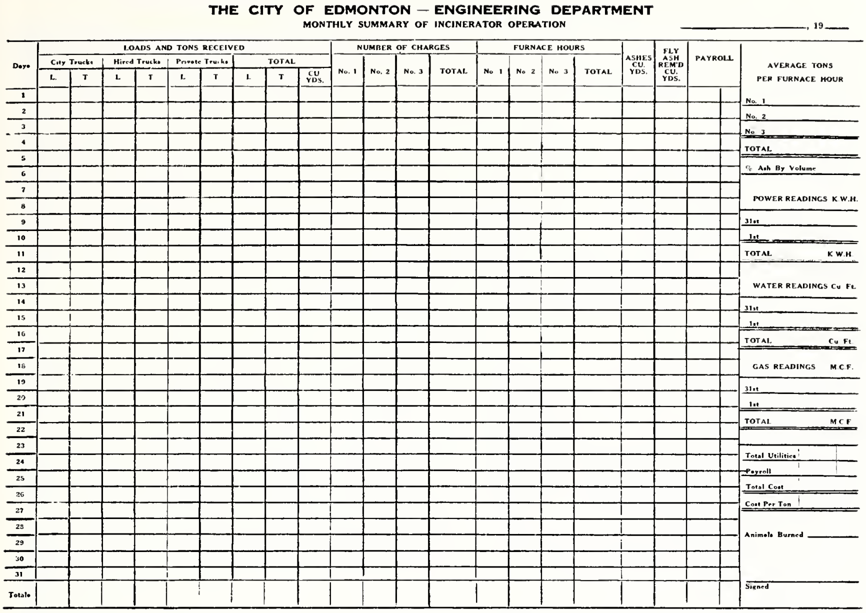
SIGNED

(Continue remarks on other side)

77-132

Fig. 144. Form used in Philadelphia for reporting bi-weekly on incineration plant operations.

Other aids to keeping accurate records and accounts are a charge-a-plate (Figure 147) issued to private refuse collectors who must pay to dispose of refuse at city facilities. Another is a receipt form for refuse received from a private collector (Figure 148), which can be forwarded



THE CITY OF EDMONTON — ENGINEERING DEPARTMENT

MONTHLY SUMMARY OF INCINERATOR OPERATION

______________, 19____

Days	LOADS AND TONS RECEIVED									NUMBER OF CHARGES				FURNACE HOURS				ASHES CU. YDS.	FLY ASH REM'D CU. YDS.	PAYROLL
	City Trucks		Hired Trucks		Private Trucks		TOTAL			No. 1	No. 2	No. 3	TOTAL	No 1	No 2	No 3	TOTAL			
	L.	T	L	T	L	T	L	T	CU YDS.											
1																				
2																				
3																				
4																				
5																				
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23																				
24																				
25																				
26																				
27																				
28																				
29																				
30																				
31																				
Totals																				

AVERAGE TONS PER FURNACE HOUR

No. 1 ____

No. 2 ____

No 3 ____

TOTAL ____

% Ash By Volume ____

POWER READINGS K.W.H.

31st ____

1st ____

TOTAL ____ K.W.H.

WATER READINGS Cu Ft.

31st ____

1st ____

TOTAL ____ Cu Ft.

GAS READINGS M.C.F.

31st ____

1st ____

TOTAL ____ M.C.F.

Total Utilities ____

Payroll ____

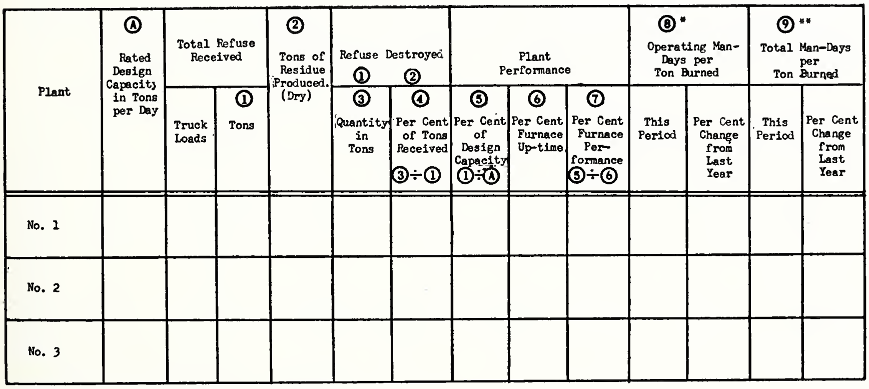
Total Cost ____

Cost Per Ton ____

Animals Burned ____

Signed ____

Fig. 145. Form used in Edmonton, Alberta, Canada, for reporting monthly on incineration plant operations.

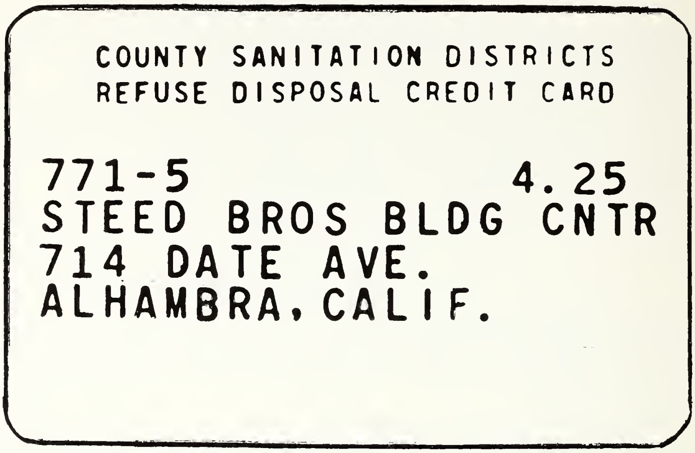


Plant	Ⓐ Rated Design Capacity in Tons per Day	Total Refuse Received		② Tons of Residue Produced. (Dry)	Refuse Destroyed ① ②		Plant Performance			⑧* Operating Man-Days per Ton Burned		⑨** Total Man-Days per Ton Burned	
		Truck Loads	① Tons		③ Quantity in Tons	④ Per Cent of Tons Received ③÷①	⑤ Per Cent of Design Capacity ①÷Ⓐ	⑥ Per Cent Furnace Up-time	⑦ Per Cent Furnace Per-formance ⑤÷⑥	This Period	Per Cent Change from Last Year	This Period	Per Cent Change from Last Year
No. 1													
No. 2													
No. 3													

*Total plant manpower, including residue hauling.

**Total of column 8 plus plant supervisory, housekeeping and security manpower.

Fig. 146. Form for reporting performance and manpower utilization for incinerator operations (exclusive of fixed administrative overhead). This type of report gives management comparative information on performances in several incineration plants and on a weekly, monthly, or annual basis. With modifications the form can be used to report performance at landfills.



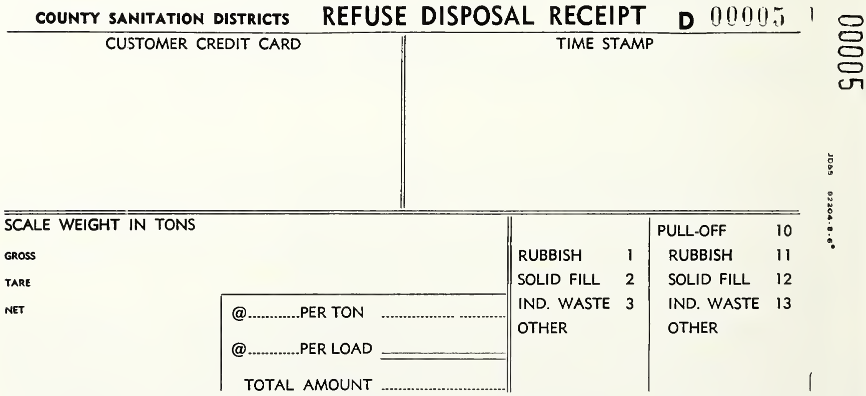
COUNTY SANITATION DISTRICTS
REFUSE DISPOSAL CREDIT CARD

771-5 4.25
STEED BROS BLDG CNTR
714 DATE AVE.
ALHAMBRA, CALIF.

Fig. 147. Charge-a-plate issued by the Los Angeles County Sanitation Districts to private contractors who use the districts' refuse disposal facilities and pay a fee for the use of them.

to the accounting office where the information is punched on cards to facilitate billing.

In any event, tabulating and reporting data on refuse disposal operations are useless unless the information is properly analyzed; and analysis of tabulated data and physical operations is useless unless action is taken to change operations if change is desirable. When performance data are properly used, operations can be improved and costs reduced.



COUNTY SANITATION DISTRICTS REFUSE DISPOSAL RECEIPT **D** 00005

00005

JD85 02204-B-6

CUSTOMER CREDIT CARD	TIME STAMP

SCALE WEIGHT IN TONS

GROSS

TARE

NET

@............PER TON ....

@............PER LOAD ____________

TOTAL AMOUNT ....

		PULL-OFF	10
RUBBISH	1	RUBBISH	11
SOLID FILL	2	SOLID FILL	12
IND. WASTE	3	IND. WASTE	13
OTHER		OTHER	

Fig. 148. Form showing receipt of refuse for disposal collected by private contractors who use Los Angeles County Sanitation Districts' disposal facilities.

Financing Disposal Operations

About 70 per cent of the cities in the United States finance disposal operations out of general tax revenues; the balance charge fees to finance operations. However, most of those cities that charge for disposal of refuse by private collectors, industries, and businesses do not charge for disposal of refuse from residences.

A survey by the American Public Works Association in 1959 showed that most large cities charge private refuse haulers and businesses and in-

TABLE 43

CHARGES TO PRIVATE USERS OF MUNICIPAL INCINERATION PLANTS IN 40 CITIES, 1959

City	Pop. (thous.)	No.days/wk. Operated	Dumping Hours	Charge to Priv or Comrl. Haulers Deliv. Refuse to Plant	Charges Collected by			Type Refuse Accepted	Charges Used For		
					Cash at Plant	Tickets	Remarks		Genrl. Opera.	Plant Debt Retire	Genrl. Fund
Birmingham, Ala.	36[1]	5½	6A - 2P	None				c			
Los Angeles, Calif.	2,423	6	24 hrs.	$3.00/T or 15¢/100 lbs. 75¢ Minimum Charge	x		Charge Acct. with city billing	1 plant-a 1 plant-c			x
Santa Monica,Calif.	87	6	-	Yes	x		Some firms billed monthly	d	x		
Hartford, Conn.	187	5	6:30A-6P	None[2]				d			
Waterbury, Conn.	115	6	8A - 4P	None				d			
Wilmington, Del.	115	5	7A - 7P	None				-			
District of Columbia	900	5	1P - 8P[3]	None				c			
Miami, Fla.	450	7	24 hrs.	None for refuse from within city[4]			Monthly Billing	b		x	
Tampa, Fla.	300	5	7A - 3P	None							
Atlanta, Ga.	500	7	24 hrs.	None				d			
Evanston, Ill.	74	5	7A - 5P	$3.50/T	x		Some Charge Accts.	c			x
Cedar Rapids, Iowa	93	5	7A - 6P[5]	None				c			
New Orleans, La.	650	6	6A -11P[6] 6A - 6P[7]					2 plants-b 1 plant -c			
Shreveport, La.	180	6	6A - 8P	None				e			
Baltimore, Md.	1,000	6	7A - 4P	None[8]				-			
Wash. Sub. San. Comm. Hyattsville, Md.	226	6	8A - 4P	$4.00/T	x		Some firms billed monthly	b	x		
New Bedford, Mass.	105	5	-	9				e			
Worcester, Mass.	203	5	8A - 3P	None				c			
Royal Oak, Mich.[10]	315	5	8A - 6P	$4.50/T Cities by Contr. $5.00/T Private	x		Private-Cash At Plant Munic.-Billed Monthly	e e	x	x	x
Minneapolis, Minn.	553	5	8A - 5P	$4.00/T dry; $9.00/T Wet			Some billed monthly	e			x
St. Louis, Mo.	868	5	8A - 4P[11]	$3.00/T (Min. 50¢)	x		Regulars billed monthly	e			x
Omaha, Neb.	282	-	7A - 7P	None				e			
Buffalo, N. Y.	650	5	6A - 9P	$2.50/T[12]	x		Charge Accts.also	e			x
New Rochelle, N. Y.	76	6	7A - 3P	$1.50/T[13]	x	x[14]	Regular users purchase tickets at DPW office or incinerator	e			x
New York, N. Y.	8,300	5½	7A - 7P	40¢/cu.yd. uncompacted[15] 55¢/cu.yd. compacted		x[14]	Tickets obtained from Dept. of Sanitation[15]	b			x
Cincinnati, Ohio	551	5	7A - 7P	None (provided wastes from within city)				e			
Cleveland, Ohio	950	7	City:7A-4P Priv:4P-7A	None[16]				d			
Portland, Oregon	407	6	8A - 5P	50¢/cu.yd.for less than 2[10]; 20¢/cu.yd. for more than 2 cu. yds.[17]				b			x
Erie, Pa.	140	5½	12:05A 12:05P	None				e			
Philadelphia, Pa.	2,100	6	24 hrs.	$2.00/T[18]			Billed monthly	d			x
Memphis, Tenn.	500	7	24 hrs.	None				b			
Houston, Tex.	825	6	6A - 10P	No comr. or priv.hauled ref.accepted at plant				c			
Alexandria, Va.	90	5½	9A - 5P	$1 tag for each vehicle							
Arlington, Va.	170	6	8A - 4P	$2/T chg.to Federal Agen.			Billed Monthly	e		x	x
Green Bay, Wisc.	66	5	7A-3:30P	None				e			
Kenosha, Wisc.	60	5	7A - 4P	None				c			
Milwaukee, Wisc	750	5	8A - 4P	$4/T; $1 each 500 lbs. or fraction thereof		x[14]	Tickets purchased at DPW office,City Hall	d			x
Racine, Wisc.	84	5	8A - 4P	None				d			
Winnipeg, Man.				$2.50/T dry; $5/T -Wet[19]							
Toronto, Ont.	656	5	7A - 3P	None[20]							

Code to Type of Refuse Accepted:
a. Rubbish (comb. or non-comb.)
b. Combined or mixed refuse
c. Combustible rubbish
d. Garbage and comb. rubbish
e. Garbage and combined rubbish

---

1. Served by Plant
2. $100/yr. pd. by neighboring city for disposal of dead animals
3. Dumping at landfill 7:30 A-4P
4. $3/T charge to priv.haulers; $3.50/T for Miami Beach
5. Pit Open 6 days to receive refuse
6. Two plants
7. One plant
8. Min. chg. $2/T is contemplated
9. New plant. Some policies not yet determined.
10. South Eastern Oakland County Garbage and Rubbish Authority
11. Material received 7 days/wk. from business establishments
12. Ordinance introduced to raise fee to $5/T effective August 1.
13. Up to 500 lbs. $1.00; 500 lbs. to 1T $1.50; 1T - 2T $2.00; 2T - 3T $2.50; 3T - 4T $3.00; 4T & up $3.50 for 1st 4T, 50¢ for each additional T
14. Tickets are numbered, purchasers name recorded and may be revoked for violation of plant rules.
15. Electro magentic weighing systems under construction will utilize automatic weighings and IBM processing of all recorded data Wt. data collection is programmed for 1960.
16. Charge planned when new plant opened.
17. Fees charged for priv. haulers other than collectors licensed by city; $550/vehicle for those hauling from within city; $800 for hauling from without.
18. No charge to any non-profit religious, educational or charitable institution or any public housing agency when refuse delivered to plant.
19. 25¢/100 lbs. for less than 1T lots
20. Amount limited to 500 lbs./day

dustries that use municipal refuse disposal facilities from $1.50 to $5 a ton of refuse disposed of, and that the average is $3 a ton. The bases of the charges differ, however. For instance, Tacoma, Washington, charged 50 cents to $1.50 per load; Sandusky, Ohio, charged 12½ cents per 100 pounds, with a minimum of 25 cents; Morgantown, West Virginia, charged $4.50 a ton with a minimum of $1; Pendleton, Oregon, charged 25 per cent of the collection charge; Marion, Ohio, charged 35 cents per cubic yard of refuse disposed of.

Special Administrative Considerations

Administrative considerations of special interest to refuse disposal planners, officials, and supervisors include (1) selection and maintenance of the correct equipment to insure dependable operations; (2) provision and management of stand-by facilities and capacity; (3) prevention of nuisances and hazards; (4) provision of services to rural and semirural areas; (5) establishment of a good public relations program; (6) development of suitable work standards; and (7) control of private users of facilities.

Selection and Maintenance of Equipment

Trouble-free operation of refuse disposal facilities requires that equipment be selected carefully and maintained properly. It must be sufficiently rugged to withstand the wear and tear to which it is subjected. It is foolhardy to think that purchasing equipment on the basis of low initial cost will necessarily save money. Equipment should be simple and practical. Both plant and equipment should be designed for dependable operation under the most extreme loads to which they are likely to be subjected.

Justification for the purchase of adequate equipment takes into account amortization and operating and maintenance costs. It also takes into account the public acceptance and good will that are generated by uninterrupted and adequate services. Overtime work and disrupted operations resulting from mechanical failures may be much more expensive than the cost of high quality equipment to begin with.

A sound maintenance program is needed to keep disposal equipment in top operating condition. The most important element in such a program is advance planning—knowing enough about each item of equipment to be able to determine the best time to withdraw it from operation for examination, testing, and any needed rehabilitation. Orderly replacement of equipment should be done routinely. That it is a mistake to operate equipment until it fails is a well established fact; nevertheless, penurious budget authorities and legislatures often do not permit the establishment of proper preventive maintenance programs through lack of understanding.

Planned maintenance involves three operations. The first two are preventive, calling for routine inspections on a daily and a monthly basis and the making of necessary minor repairs. The third is a complete periodic overhaul. Through proper scheduling of inspections, repairs, and overhauls, incipient defects that might lead to operating difficulties are discovered in time to permit routine corrections and thus avoid some major repairs and replacements.

For preventive maintenance to be fully effective, backlogs of work must be avoided. Often this is difficult to achieve, but a course of action that initiates preventive maintenance as each new facility is completed and put into operation helps to this end.

Stand-By Facilities

Stand-by capacity to take care of peak loads, heavy seasonal loads, and breakdowns is necessary to avoid nuisances and unsanitary conditions. The possibility of multiple simultaneous breakdowns should be anticipated and reasonable care taken so that the effects of such occurrences are not disastrous. Since refuse disposal is to a great extent a materials handling process, and, since some types of material cause rapid deterioration of equipment, a disposal operation should make adequate provision for emergencies and extended down-time. These provisions may include stand-by or alternative equipment or facilities, oversize storage bins, or arrangements with neighboring municipalities for use of their facilities. If sufficient stand-by arrangements have not been made, other less satisfactory methods must be used or refuse must be allowed to accumulate. Either of these courses of action is likely to result in nuisances and potential health and fire hazards.

In spite of shortcomings, it is well to investigate the possibilities of using at least for short periods less desirable though adequate alternatives to take care of excess amounts of refuse during peak periods—or even all the refuse if a plant breaks down. For example, all refuse can be deposited in a landfill that is normally used only for disposing of incinerator residue and other noncombustibles. It should be recognized, however, that hauling refuse to a landfill may be more expensive than providing proper stand-by facilities.

Prevention of Nuisances and Hazards

Good administration of a disposal operation involves providing for as many safeguards against the possibility of nuisances and hazards as can be justified economically in light of their probable frequency and degree. Many safeguards, such as a fire extinguisher, a hose and pump connected to a small water storage tank, or a shallow well or hydrant as protection against fire at a landfill site, are relatively inexpensive.

The number of spare parts that should be kept on hand for an overhead crane used at an incineration plant, for instance, has to be determined by realistically forecasting the frequency of breakdowns in relation to the time required to get the parts from the manufacturer or his distributor.

When a poor disposal facility such as a burning dump is shut down, the municipality should take steps to prevent rodent and insect migration. A concerted rat-baiting and insect-spraying program, following good pest control practices, will protect the neighboring area from a potentially dangerous situation.

Services to Rural and Semirural Areas

Refuse disposal problems in rural and semirural areas relate to, among others, farms; strip developments along highways, rural roads, and streams; fringe areas of towns; and unincorporated communities.

These refuse disposal problems involve special management considerations. Most problems pertain to health but there are also problems relating to the jurisdiction that provides disposal services. These latter involve such matters as storage, transportation, disposal, funds available, regulations, and enforcement.

Farms usually present no serious problems; farm animals and poultry provide easy disposal for most garbage. Combustible rubbish is disposed of by burning and noncombustible rubbish is allowed to accumulate until there is enough to justify hauling it away or burying it.

Strip development areas are usually without their own local government or facilities to carry on refuse disposal as a public undertaking. In such instances, where the volume of work justifies, it may be practical for the county to provide collection and disposal services through scavengers or private collectors that it licenses. If a scavenger disposes of garbage by feeding it to pigs, he must conform to state and local health regulations.

In fringe areas and in unincorporated communities, cooperation of adjoining cities in providing collection and disposal services is desirable. The cost of such services may be met by fees charged to the householder or business or the county government may reimburse the city. When this arrangement is not practical or acceptable it may be advisable to have the service carried out by licensed scavengers, as in strip developments. There are also instances where refuse disposal service is provided to such areas through sanitation or garbage districts.

The operating personnel engaged in providing services to unincorporated towns, villages, and other small places should have a variety of skills. A bulldozer operator, for instance, may be used part-time as a truck driver, or his services may be divided between the street department and the department of sanitation. Such divisions of time are not a disadvantage provided competent personnel can be employed. If employees do not have sufficient technical knowledge to guide disposal operations, state health agencies usually will assist in training them.

Responsibility for sanitary refuse disposal rests with government officials, no matter what the form or size of government. There should be a basic willingness on the part of the governing body to meet sanitation standards and it should make a sincere effort to convince the public of the need for such standards and of the need for funds to provide adequate services. When officials are unwilling to take the initiative, interested citizens and citizen groups can work to bring about community consciousness of need and to secure the necessary action.

Local conditions and the size of the disposal operation help to determine the most satisfactory operating procedure—that is, whether public employees, licensed scavengers, or contract services should be used. More important than procedure is the matter of suitably trained employees and adequate supervision. Periodic inspections of sanitary conditions by state health authorities can be helpful; and often supervision is necessary to prevent regression of standards of sanitation.

Public Relations Program

Securing public approval and engendering confidence in refuse disposal operations are the objectives of public relations programs. The success of operations depends to a large extent on public understanding of the disposal function—its problems and the steps taken to overcome them—and public knowledge that a real effort is being made to give good service. Success also depends on awareness on the part of the responsible officials of public desires for service and of the social changes that are taking place in the city.

Good public relations are best secured by doing an outstanding job of refuse disposal—by providing first class facilities and dependable operations. Yet good service and administration are not enough in most cities. Refuse disposal deals with obnoxious materials that have long been associated in the public mind with obnoxious disposal methods. Although a service is performed, it is a negative one in which materials and objects are destroyed rather than created. Many residents remember the days of open dumps, inadequately designed and operated incineration plants, and many poor practices that are a part of the history of refuse disposal. Attention therefore should be given to publicizing the facts that technical and operational advances have been made in refuse disposal and that accepted methods and practices permit safe disposal without nuisances.

A public relations program should emphasize improvements in methods and procedures of refuse disposal. But it should also be based on attractive plants and sites, as good looking buildings and well landscaped and maintained grounds contribute a great deal to the public's opinion of the operation.

Employees in direct contact with the public who are well trained in and practice courtesy and cooperation contribute substantially to good public relations. Although normally only a minority of refuse disposal employees have direct contact with the public, one rude, uncooperative employee can destroy a disproportionately large amount of public good will.

Suitable Work Standards

It is important to good administration to develop and adhere to suitable standards of work. Quantity standards for work production are necessary to budgeting in determining manpower and equipment requirements; they are also necessary in evaluating the performance of individual employees and machines. Quality standards are necessary in meeting public health requirements consistently. Unfortunately, quality standards have not been established for all facets of disposal—incinerator residue, for example. Although there are air pollution regulations in many cities in which an attempt has been made to set acceptable standards for stack emissions, for instance, such standards are not usually applicable to incineration of refuse because they do not recognize local and seasonal tolerances and climatic conditions. These and other standards for incineration, for landfills, and for the other disposal methods are discussed elsewhere in this manual.

It is the responsibility of management to work for the improvement of standards. Management should also insure that established standards are met, first by communicating them to all operating personnel involved and then by providing a reporting, recording, and inspection system that permits management constantly to control performance.

Control of Private Use of Facilities

The private use of municipally owned disposal facilities must be carefully controlled. Methods include (1) licensing of commercial users; (2) establishment of standard fees for users; (3) development of a practical method for billing or for advanced sale of dump tickets; (4) establishment and strict enforcement of regulations; and (5) keeping of records of those who do not comply with regulations and denying use of the facilities to those who repeatedly violate the regulations.

In Conclusion

The tremendous postwar growth of urban areas is continually reducing the amount of space available for refuse disposal in landfills. As a result, there is increased demand for the use of incineration or other practical disposal methods that do not require as much space but are economical, sanitary, healthful, and nuisance-free.

The trend, therefore, at least in large metropolitan areas, is toward highly mechanized incineration plants, which reduce man-hour needs and operating nuisances. Recognizing this trend, management should work consistently to recruit or train highly skilled personnel and to improve operating efficiency through the use of sound accounting and reporting systems. Electronic data processing machines are needed in large operations for computing and record keeping. Employee unions are growing in importance, and management should foster good working relationships with them. The administrator should lead and cooperate in improving working conditions, safety practices, in-service training, and other services and practices that will contribute to an efficient and effective disposal system.

Refuse disposal is already big business in many cities and it is growing bigger year by year. Municipalities must recognize this growth and provide, through enlightened management, for continuing improvement in techniques and standards so that ever more effective refuse disposal will be assured.

APPENDIXES

Appendix A

TENTATIVE METHODS OF ANALYSIS OF REFUSE AND COMPOST

Initial Sampling
General Instructions
Tests for Moisture (Water)
  Oven Drying Method
  Infrared Method
  Toluene Distillation Method
Test for Volatile Solids and Ash
Test for Lipids (Ether Extract)
Test for Liquids
Test for Crude Fiber
Test for Sugars
Tests for Starch
  Anthrone-Sulfuric Acid Method
  Direct Acid Hydrolysis Method
Test for Carbon
Test for Nitrogen (Organic and Ammoniacal)
  Kjeldahl-Wilfarth-Gunning Method
Test for Protein
Test for Carbon-Nitrogen Ratio
Test for Phosphorus (Phosphate)
Tests for Potassium (Potash)
  Flame Photometric Method
  Sodium Tetraphenyl Borate Method
Test for Hydrogen-Ion Concentration (pH)
Test for Gross Calorific Value
Test for Net Calorific Value
Test for Sulfur
Test for Hydrogen and Carbon

This appendix is the first compilation of proposed methods for the examination of solid and semi-solid wastes—particularly domestic refuse. The tests described were selected because of practical experience with them in several comprehensive municipal studies. Several of the methods of testing were developed or adapted for use by the Technical Development Laboratory Communicable Disease Center of the United States Public Health Service in Savannah, Georgia.[1]

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[1] Wiley, John, and Spillane, Janet T., *Methods for Examination of Raw and Composted Organic Wastes*. Chemical Memorandum No. 4, U. S. Public Health Service, Communicable Disease Center, Technical Development Laboratories (Savannah, Ga.: U. S. Public Health Service, 1956), 24 pp. (mimeo.).

Assay of Carbon-14 Labeled Materials and Determination of Total Carbon in Organic Materials by Induction Furnace Combustion Technique. Chemical Memorandum No. 5, U. S. Public Health Service, Communicable Disease Center, Technical Development Laboratories (Savannah, Ga.: U. S. Public Health Service, 1958), 9 pp. (mimeo.).

It is hoped that careful use and evaluation of the tests will lead to the adoption of more uniform and efficient methods of solid waste analysis. The tests may also be of value in analyzing agricultural, industrial, and commercial solid wastes and products of their decomposition.

Analysis of refuse is helpful—and even necessary in many cases—in planning and designing refuse disposal systems and facilities, in operation of the facilities, in evaluation and grading of facilities by operators and by regulatory agencies, and in pilot studies and research on methods of disposal and treatment. They are especially useful in planning and designing incineration and composting plants and in determining whether salvage is worthwhile. Various types of chemical tests made of the refuse used in composting are valuable in regulating the production cycle and controlling the quality of the end product.

Standard analysis methods also make possible standard reporting, which is necessary if the results of tests from different cities are to be accurately compared. It is also important to keep records of refuse components by the 10 categories listed below over a number of years to ascertain trends in refuse production. Little or no time is saved if records are kept by fewer categories.

Most solid wastes consist of refuse, as defined in Chapter 1 and classified in Table 3. Sampling and analyses are usually made on the basis of how refuse is collected in a city: combined or mixed, rubbish, combustible refuse with or without garbage, and garbage. Less important kinds of refuse also analyzed on the basis of how they are collected are ashes, street refuse, yard rubbish (if collected separately), and sewage solids (if they are disposed of with refuse or some of its components). Of minor importance in chemical analytical studies are noncombustible refuse, dead animals, abandoned automobiles, and construction and demolition refuse. Some kinds of refuse, such as explosives, pathological and radioactive wastes, and some industrial wastes, may require special analytical methods not discussed here.

Since accurate and reproducible chemical analysis requires small and finely ground samples of refuse, it is necessary to separate all components that cannot be finely ground and that can be analyzed by estimating rather than by laboratory methods. Separation categories vary with the investigator. Ten are listed, but only one (item 9 below) requires chemical analysis. They are:

1. Cans
2. Bottles
3. Ferrous metals
4. Nonferrous metals
5. Rags
6. Paper
7. Plastics, leather, rubber
8. Wood, limbs, sawdust
9. Food wastes, grass clippings, leaves
10. Bricks, stones, dirt, ashes

Refuse quantities are best measured by weight and reported in terms of pounds per capita per year or per day. By taking the weight and preferably the volume of the refuse components in each of the 10 categories, it is possible to reconstruct on paper the composition of the refuse samples. Some authorities believe that this procedure gives more accurate results than if a refuse sample that had not been separated into its components had been ground and analyzed.

The composition of commercial and industrial refuse usually varies so much that accurate weights and analyses are not practical. Information about such refuse can be gotten by stationing men at disposal points who can estimate volumes and weights and the percentage of refuse in each of the major categories.

Initial Sampling

Relatively large initial samples of most mixed refuse materials are required because of the extreme heterogeneity and particle size range. It is suggested that a quarter of a truckload, or not less than 500 pounds, of such materials as mixed refuse or rubbish be taken for the initial sample. Unless samples are to be taken in many sections of the city, the refuse should be collected from an area in which conditions are average and from a number of premises.

Sampling and sample preparation should be done rapidly to avoid excessive change in moisture content. The sample should be ground in a small grinder or shredder immediately after it is brought in. Gloves and safety goggles should be worn by the operators and a respirator should also be worn if the grinding creates dusty conditions. The material should be ground so that no particle exceeds 1½ inches. A grating with 6-square-inch openings or a roller screen with about 1½-inch spacing should be used. If the grating or screen clogs frequently it may save time to double grind: first coarse and then finer.

The ground sample should be mixed rapidly on a smooth, clean, impervious floor or slab with a shovel; the materials should be cut in quarters; and a shovelful extracted from each quarter. The four shovelfuls are combined and mixed rapidly as before and again are quartered. Again four samples are collected, one from each quadrant, as explained under the section, "Tests for Moisture, Oven Drying Method." Because all subsequent analyses are conducted with oven-dried material, this method of obtaining moisture is recommended. It is the first step in preparation of samples for other analyses. In addition to providing four replicates for the moisture determination, the four samples provide sufficient dried materials for all subsequent analyses that may be required. If less accuracy is desired or less dried material is required for additional analyses, the number of replicates may be reduced to two.

General Instructions

All samples analyzed by the following methods, with the exception of moisture and pH determinations, should be taken in duplicate, dried to constant weight at 75° C., ground to pass a 1 millimeter sieve, and stored in widemouth, screw top jars. They should be from 50 to 100 grams (wet weight) or larger to insure representative samples. Larger samples require excessive drying periods but may be needed if the material sampled is coarse. A sufficient number of replicates are required to provide sufficient dry material for all subsequent analyses.

Before the analyses are made, the samples or aliquots should be redried at 75° C. for at least two hours to eliminate moisture picked up during grinding or transferring of the samples. The dry weight of the sample may be obtained by difference (i.e., carefully transferring redried material from light sample containers) or directly by placing the approximate amount of sample in the tared dry flask or crucible, redrying, and weighing.

Covered containers with small tare weights are required for accurate results. Samples from drying ovens or muffle furnaces should be cooled to room temperature in desiccator jars or cabinets containing desiccant. Dry weights are most accurately obtained by rapid weighing in glass encased laboratory balances provided with desiccant. All results, except for moisture and liquid content and pH, are reported on a per cent dry weight basis. Moisture and liquid are reported on a wet (total) weight basis. No attempt should be made to preserve or transport fresh (moist) samples, but dried samples may be stored or shipped. All water used in analysis should be distilled.

Tests for Moisture (Water)

There are three methods of making moisture tests: (1) oven drying; (2) infrared; and (3) toluene distillation. The oven drying method is the one of choice because it is more accurate than the others and is a step in the preparation of samples for subsequent analyses. It should always be used in perference to the other tests unless it is necessary to get an answer rapidly and it is not necessary to have complete accuracy.

Oven Drying Method

Equipment: Drying oven, preferably with forced air circulation; large desiccator jar or cabinet and desiccant; sample containers (covered aluminum cans about 3½ inches in diameter and 2 inches deep have proven satisfactory); triple beam balance graduated to 0.1 grams (an analytical balance is satisfactory if it has a capacity of 200 grams).

Procedure: Duplicate samples of 50 to 100 grams of fresh ground refuse, compost, or other organic wastes are taken in tared sample containers and immediately covered. Inorganic materials such as glass, metal, and ceramics a ½-inch or larger are discarded. Material should not be packed down. Samples should be weighed to the nearest decigram within an hour and dried to a constant weight in drying oven at 75° C. with lids cocked or off. With samples of less than 60 per cent moisture content, drying for 24 hours in a forced air oven may be sufficient; 48 hours are preferred. Drying at 75° C. is preferable to drying at 103° C. because it permits retention of more of the volatile constituents other than water (particularly ammonia-N and lipids). With materials containing free liquid (70 to 75 per cent or more water) such as raw garbage or sewage sludge, most of the water may be evaporated first on a steam bath, with final drying in the oven. The sample is then cooled in a desiccator jar or cabinet with lids on, and it is weighed.

$$\textit{Calculation:}\ \frac{100\ (\text{loss in weight})}{(\text{net wet weight})} = \%\ \text{moisture (wet basis)}$$

The value is approximately equal to per cent water by weight and should not be confused with per cent liquid.

Infrared Method

The infrared method provides a rough approximation of moisture content in a much shorter time than the oven drying method does. It is suitable, for instance, if it is necessary to know rapidly the amount of moisture in refuse for control of an incineration or composting plant. It is not suitable as a means of drying samples for subsequent analyses because it may volatilize substances other than water.

Equipment: Moisture balance of infrared type with 25-gram sample pan.

Procedure: Directions supplied with the instrument should be followed. Most moisture balances read directly in per cent moisture for the size of the sample specified. Care must be taken to insure clean sample pans, accurate centering and balancing, and sufficiently low setting of powerstat dial to insure against charring or burning the sample. The infrared lamp should be operated with the lid closed to avoid charring or burning the refuse sample.

Toluene Distillation Method[2]

The toluene method is based on the distillation of water from a refuse sample that has been immersed in toluene at boiling temperature—110.8° C. Toluene and water vapors condense in the trap, but they are immiscible so the toluene, being lighter, fills the upper part of the trap, the excess spilling back through the distilling tube to the flask, and the water collects in the graduated part of the trap. The method is more rapid but less accurate than oven drying and is recommended primarily for plant control.

Equipment: Water determination apparatus consisting of a 250- to 300-milliliter Pyrex Florence or Erlenmeyer distilling flask connected by a distilling tube receiver and trap calibrated from 0 to 20 milliliter in 0.1 milliliter divisions; and a 20-inch sealed-in straight-tube Liebig condenser, preferably with ground glass connections (see Figure A-1). (Some laboratory supply houses have the complete apparatus made up; if that is the case, the 20-milliliter trap should be specified because 5- to 10-milliliter traps are more common.)

Reagents: Toluene, purified.

Procedure: The apparatus must be clean and dry; the trap and condenser should be cleaned with dichromate cleaning solution, thoroughly rinsed with water and with acetone or alcohol, and dried in the oven. Weigh into the flask to the nearest 0.1 grams the amount of fresh refuse sample that can be expected to have between 15 to 20 milliliters of water (i.e., a sample thought to contain about 60 per cent moisture should be approximately 30 grams in fresh weight). Add sufficient toluene—about 75 milliliters—to cover the sample completely. Connect the apparatus, turn on the cooling water, and fill the trap with toluene to the level of the distilling (overflow) tube by pouring through the top of the condenser.

Bring to a boil on a hot plate and distill at about 2 drops per second until most of the water passes over, and then increase the rate to about 4 drops per second. When all the water apparently is over, wash down the condenser tube by pipetting 5 to 10 milliliters of toluene into the top. Continue distilling a short time to ascertain whether any more water will distill over. If it does, repeat the washing process. If drops of moisture remain in the condenser, remove them by brushing down with the tube brush attached to a copper wire and saturated with toluene, washing down condenser at the same time. The entire process usually requires 30 to 40 minutes. Allow the receiving trap to come to room temperature. Read volume of water and calculate to per cent moisture (wet weight basis).

TEST FOR VOLATILE SOLIDS AND ASH

Equipment: Drying oven; analytical balance; desiccator jar; porcelain cru-

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[2] Association of Official Agricultural Chemists, *Official Methods of Analysis* (8th ed.; Washington, D. C.: The Association, 1955), p. 367.

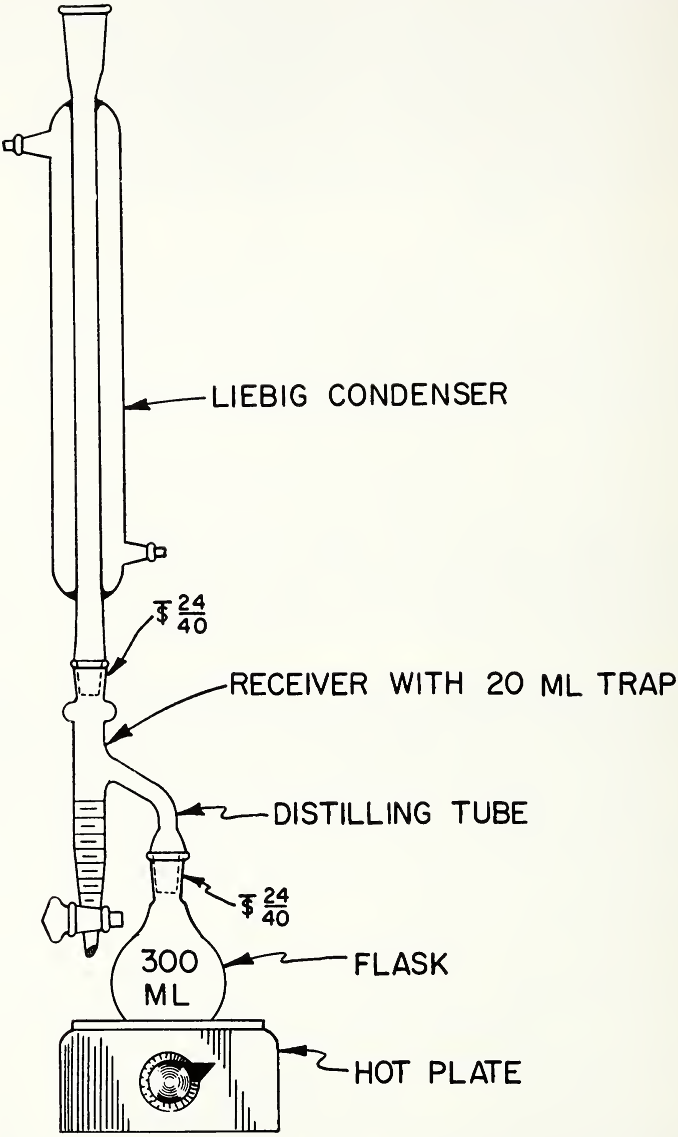
LIEBIG CONDENSER
$ 24/40
RECEIVER WITH 20 ML TRAP
DISTILLING TUBE
$ 24/40
300 ML
FLASK
HOT PLATE

Fig. A-1. Toluene distillation apparatus for moisture determination.

cibles, high form No. 1, 1A, or 2; muffle furnace with indicating pyrometer and rheostat temperature control.

Procedure: Transfer 3 to 6 grams of dried and ground sample to a previously ignited and tared crucible. Redry for 2 hours at 75° C. and obtain sample weight directly to nearest centigram. Place the crucibles in a cold muffle furnace and gradually bring the temperature to 600° to 650° C., with the door raised about ½-inch. Muffle at this temperature for 2 hours; cool in desiccator and weigh.

$$\textit{Calculation:}\ \frac{100\ (\text{loss in weight})}{(\text{net dry weight})} = \%\ \text{volatile solids}$$

This value approximates the per cent organic matter of the material. The value for per cent ash is 100 minus per cent volatile solids.

TEST FOR LIPIDS (ETHER EXTRACT)[3]

Lipids (oils, greases, fats, and waxes) have a heat equivalent (calorific) value of about 16,700 B.T.U. per pound, or more than twice that of other common combustible constituents of refuse. They are liquids at thermophilic composting temperatures.

Equipment: Soxhlet extractor with 125-milliliter flask; water bath or low-temperature heater; extraction thimbles (Whatman, 22- by 80-millimeter, fat extracted); steam bath in exhaust hood; drying oven; analytical balance; desiccator jar; sample containers (covered aluminum cans about 2 inches in diameter by ⅞-inch deep).

Reagent: Ether, c. p. anhydrous (ethyl).

Procedure: Redry a portion of the ground sample refuse in an aluminum can at 75° C.; cover, cool in desiccator, and weigh. Transfer about 5 grams of redried and ground sample to an extraction thimble, obtaining sample weight indirectly to nearest milligram; obtain dry tare weight of extraction flask. Add about 80 milliliter of ether to the extraction flask, place thimble in extraction tube, and extract continuously in Soxhlet extractor for 16 to 18 hours on the water bath. Extraction temperature should be regulated so that extraction tube discharges every 5 to 10 minutes. Make up ether loss if necessary. Cooling condenser with ice water instead of tap water will conserve ether better. Evaporate ether from flask under hood over a steam bath and continue drying in oven for 1 hour at 75° C. Cool flask in desiccator and weigh. Redry to constant weight.

$$\textit{Calculation:}\ \frac{100\ (\text{weight of ether extract})}{(\text{net dry weight})} = \%\ \text{lipids (ether extract)}$$

While the value obtained is for ether extractable matter and includes all substances soluble in ether, it represents essentially the lipids content.

TEST FOR LIQUIDS[4]

The liquid content of wastes to be aerobically composted may be more meaningful than the moisture content of some wastes, particularly those with high lipids content, high ash content, or both. The reason that liquid content may be important is that while a certain degree of water is required for microorganism metabolism, too much liquid in any form hinders aeration.

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[3] Wiley, John S., "Composting Studies, II, Progress Report on High-Rate Composting Studies" in *Proceedings, 12th Industrial Waste Conference,* May 13-15, 1957 Purdue University Engineering Bulletin, Series 94 (Lafayette, Ind., 1957), pp. 596-603.

[4] Wiley, John S., "Liquid Content of Garbage and Refuse." American Society of Civil Engineers, Proceedings Paper 1411, Sanitary Engineering Division 83, SA5 (New York, 1957), pp. 1-8.

Lipids added to the moisture content may take up excessive pore space, retarding aeration. Ash content (i.e., metal, glass, ceramics, and dirt), while it absorbs moisture, acts much like ballast. Increasing the amount of ash decreases the per cent of moisture but it does not increase air spaces. Thus with various materials, optimum moisture content for composting has a wide range. Computing the liquid content takes into account two additional important variables and narrows the range of values for optimum composting conditions. These are the lipids and the ash contents.

Procedure: The liquid content is computed from the moisture, lipids, and ash contents, all values expressed as per cent of wet (total) weight. The formula is:

$$\%\ \text{liquid} = \frac{100\ (\%\ \text{moisture} + \%\ \text{lipids})}{(100 - \%\ \text{ash})}$$

Convert lipids and ash contents from dry to wet basis before use in the above formula as follows:

$$\%\ \text{lipids (WW)} = \frac{[\%\ \text{lipids (DW)}]\ [100 - \%\ \text{moisture}]}{100}$$

Example: Moisture = 60% (WW); lipids = 12% (DW); ash = 8% (DW)

$$\text{Lipids (WW)} = \frac{12\quad(100 - 60)}{100} = 4.8\%$$

$$\text{Ash (WW)} = \frac{8\quad(100 - 60)}{100} = 3.2\%$$

$$\text{Liquid} = \frac{100\quad(60 + 4.8)}{(100 - 3.2)} = 66.9\%$$

Optimum *moisture* contents for composting three quite different wastes ranged from 52.5 to 62.5 per cent, but for the same wastes the optimum *liquid* content had a range of only 67.5 to 70.1 per cent.

TEST FOR CRUDE FIBER[5]

Equipment: Cold finger condenser, reflux, with 24/40 $T_{/s}$ joint; digestion flasks, 1. 1. (liter) Erlenmeyer, with 24/40 $T_{/s}$ joint, marked at 200 milliliter; Pyrex filtering funnel, 100 millimeter diameter; No. 40 filtering cloth (National Filter Cloth and Weaving Co.) cut into 6½-inch squares; Alundum crucibles, 25-milliliter, medium porosity; drying oven; muffle furnace; desiccator jar; analytical balance; aluminum sample containers (2-inch diameter by ⅞-inch).

Reagents: 0.255*N* sulfuric acid (14.28 milliliter concentrate H_2SO_4/2 1.); 0.313*N* sodium hydroxide (1.25 grams NaOH/100 milliliter, free from Na_2CO_3). Concentration of these solutions must be accurately checked by titration.

Procedure: Dry residue that has been extracted with ether (see procedure for lipids) in oven at 100° C. for several hours in aluminum sample container; cover; cool in desiccator; and weigh. Transfer about 2 grams of material to an Erlenmeyer flask, obtaining weight indirectly to nearest milligram. Add

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[5] A.O.A.C., *op cit.*, p. 372.

200 milliliters of boiling H_2SO_4 solution, connect flask to condenser, and heat immediately. It is essential that the contents of the flask come to the boiling point within 1 minute and continue boiling briskly for exactly 30 minutes. (A little testing will show what height of flame must be used and the burner can be marked for subsequent determinations. An Atlantic high temperature burner has proved to be efficient, and asbestos gauze should be used to prevent undue bumping.) Rotate the flask to keep the sample thoroughly wet. Take care during boiling to keep the material on the sides of the flask in contact with the solution. (A piece of rubber tubing connected to a rubber bulb can be used to introduce a blast of air at intervals to reduce foaming.) At the end of 30 minutes remove flask and immediately filter onto No. 40 filtering cloth through a filtering funnel and wash with boiling water until washings are no longer acid to litmus paper.

Bring a quantity of NaOH solution to the boiling point in a Pyrex wash bottle, using a funnel in the neck as a condenser. Wash material on filtering cloth into 1 l. flask using 200 milliliters of boiling NaOH. Connect flask with reflux condenser and boil for exactly 30 minutes. A constant watch must be kept so that the solution does not foam through the condenser and into the side arm. An air blast should be applied in the manner described for acid digestion; on some samples it will have to be applied about once a minute. Bumping can be reduced by swirling the flask occasionally. At the end of 30 minutes, remove the flask and immediately filter through No. 40 filtering cloth. Thoroughly wash the residue with boiling water to remove all NaOH and transfer to an Alundum crucible. (It is convenient to transfer the bulk of the residue to the crucible with a spatula and wash the remainder from the filter cloth into a flask from which it is easily transferred to the crucible. Filtering the NaOH solution directly into a prepared Gooch crucible has been tried but the fine particles clog the asbestos filter.) Once the residue is in the Alundum crucible, wash with several portions of boiling water and test washes for NaOH with litmus paper. Rinse with 15 milliliters of 95 per cent ETOH and dry crucible to constant weight in oven at 100° C. Cool in desiccator and weigh. Incinerate contents of crucible in muffle furnace at 600 to 650° C. for 30 minutes. Cool in desiccator and weigh.

Calculation:
$$\frac{(\text{net loss on ignition})\ (100 - \%\ \text{ether extract})}{(\text{dry weight ether extracted material})} = \%\ \text{crude fiber}$$

The formula given above corrects for ether extracted material so that the crude fiber is expressed as per cent of the total dry weight of the original sample.

TEST FOR SUGARS[6]

Reagents:

Ethyl alcohol, 50 per cent and 95 per cent.

Saturated lead acetate, Pb $(C_2H_3O_2)_2 \cdot 3H_2O$ (neutral, not basic lead acetate).

Potassium oxalate, $K_2C_2O_4 \cdot H_2O$.

Sodium carbonate, Na_2CO_3.

Calcium carbonate, $CaCO_3$.

Hydrochloric acid, HCl, concentrated.

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[6] *Ibid*, pp. 545-47, 550, 896-900.

4*N* sulfuric acid.

Asbestos (prepared according to *Official Methods of Analysis, A.O.A.C.*, 8th ed., 1955, p. 545 [Munson-Walker method for determination of sugar]).

Copper sulfate solution: 34.639 g. of $CuSO_4 \cdot 5H_2O$ in H_2O, diluted to 500 milliliters and filtered through prepared asbestos.

Alkaline tartarate solution: dissolve 173 grams of sodium potassium tartarate and 50 grams of NaOH in water and dilute to 500 milliliters. Let stand for two days and filter through prepared asbestos.

Ferric sulfate solution: dissolve 135 grams of $FeNH_4(SO_4)_2 \cdot 12H_2O$, or 55 grams anhydrous $Fe_2(SO_4)_3$, or 77.33 grams $Fe_2(SO_4)_3 \cdot n\ H_2O$ and dilute to 1 l. with water; titrate 50 milliliters of this solution, acidified with 20 milliliters of 4*N* H_2SO_4, with the $KMnO_4$ solution, and use this titer as zeropoint correction.

Ferrous phenanthroline indicator: dissolve 0.7425 grams of orthphenanthroline monohydrate in 25 milliliters of 0.025*M* $FeSO_4$ solution (6.95 grams of $FeSO_4 \cdot 7H_2O$ per l.).

Potassium permanganate solution: approximately 0.1573 N and containing 4.98 grams per l; after several days of aging, filter through asbestos or sintered glass. Standardize by one of the classic methods.

Standard invert sugar solution: to a solution of 9.5 grams of pure sucrose (table sugar is sufficiently pure) add 5 milliliters of concentrated HCl and dilute with water to about 100 milliliters; let stand three days at room temperature, then dilute to 1 l. (This constitutes an acidified 1 per cent invert sugar solution, which is very stable.) Neutralize with NaOH and dilute to desired concentration immediately before use.

Preparation of Sample: Weigh 20 grams of redried sample into a tared beaker and transfer to a 1 l. Erlenmeyer flask. Add 350 milliliters of 50 per cent ETOH, using some of the alcohol to transfer small particles adhering to the beaker and transfer funnel. If the material is acid to litmus paper, add 1 to 3 grams of Ca CO_3. Boil for one hour on steam bath with a small funnel in the neck of the flask as a condenser. Allow samples to stand for 2 to 3 days.

Filter samples quantitatively through rapid filter paper in a Buechner funnel, using suction into a 500-milliliter volumetric flask. (A little experimenting may be needed to determine the best filter paper to use. If the particles rapidly clog filter paper, a linen cloth on top of a clean paper may permit more rapid filtering.) Make up to volume with 95 per cent ethyl alcohol. Depending on the amount of sugar present, an aliquot (300 milliliters have been found to be convenient) is transferred to a 600-milliliter beaker and evaporated to about 50 milliliters on a steam bath. Transfer the residue with hot water to a 200-milliliter volumetric flask and rinse the beaker thoroughly with hot water, adding the rinsings to the contents of the flask. Add 5 milliliters of saturated lead acetate, shake the flask, and allow the contents to stand for 15 minutes, or until cool. Then make up the samples to volume with water, mix thoroughly, and filter through No. 52 and No. 42 filter papers together in a filtering funnel into a 400-milliliter beaker. Add sufficient potassium oxalate to precipitate all the lead and filter the samples again through No. 52, No. 40, and No. 42 filter papers together in a filtering funnel into a 200-milliliter volumetric flask.

Reducing Sugars: Usually the term sugars refers to total sugars. Sugars are rapidly decomposed, being essentially all decomposed or converted to simpler compounds by about the third day of aerobic mechanical composting. It may be unnecessary to determine reducing sugars but many of the steps given below are required for the total sugars determination that follows.

A 50-milliliter aliquot of the prepared solution is pipetted into a 400-milliliter beaker. (Larger amounts cannot be used; if a smaller aliquot is used, add water to total 50 milliliters.) Add exactly 25 milliliters of $CuSO_4$ and 25 milliliters of alkaline tartrate solution. Heat the beaker on an asbestos gauze over a Bunsen burner with the flame regulated so that boiling begins in *exactly 4 minutes* and continue boiling for *exactly 2 minutes.* Keep beaker covered with a watch glass during heating. Filter hot solution at once through an asbestos mat in a porcelain Gooch crucible. Wash precipitate thoroughly with hot water (60° C.), testing final rinse with litmus paper. When precipitate is thoroughly washed, rinse with 10 to 15 milliliters of 95 per cent ethyl alcohol and place in oven to dry. Transfer asbestos mat from crucible to beaker with a glass rod. Add 50 milliliters of ferric sulfate solution. (It is usually necessary to rinse the crucible with the ferric sulfate solution as a fine film of Cu_2O is generally present on the sides.) Stir the solution vigorously until the Cu_2O is completely dissolved. To examine for complete solution, hold the beaker above eye level. The Cu_2O takes some time to dissolve and it is quite often necessary to break up the precipitate with a glass rod. Add 20 milliliters of $4N$ H_2SO_4 and titrate with standard $KMnO_4$. As the end point is approached, add 1 drop of ferrous phenanthroline indicator. At the end point the reddish brown solution changes to green. The end point is very sharp and comes with almost no warning and therefore it should be approached cautiously. Obtain the weight of reducing sugar equivalent to the weight of copper from the Hammond table in *Official Methods of Analysis* (8th ed. A.O.A.C., 1955) pp. 896-900, using values for invert sugar. Conduct a blank determination using 50 milliliters of water. The method may be checked using the standard invert sugar solution in which the standard solution should analyze 1 per cent invert sugar.

Calculations:

(1) 63.57 (ml. $KMnO_4$ soln — ml. blank) norm. $KMnO_4$ = mg. copper as Cu.

(2) mg. copper = mg. invert sugar (from Hammond table)

(3)
$$\frac{(\text{mg. invert sugar})\ (\text{ml. 1st tot. vol.})\ (\text{ml. 2nd tot. vol.})}{10\ (\text{g. init. dry wt. sample})\ (\text{ml. 1st aliquot})\ (\text{ml. 2nd aliquot})} = \%\ \text{reducing sugars}$$

The factor 63.57 is the milli-equivalent weight of copper (milligrams).

Total Sugars: A 100-milliliter aliquot of the prepared solution is pipetted into a 200-milliliter volumetric flask. Add 5 milliliters of concentrated HCl and allow solution to stand at room temperature for 48 hours in order for inversion to take place. When inversion is complete, neutralize with Na_2CO_3 and dilute to 200 milliliters with water. Filter if necessary and determine reducing sugars in 50 milliliters of the solution as described above. (A larger sample may be taken and reduced on the steam bath to 50 milliliters if necessary.) A blank should be carried through the procedure for reducing sugars with each set of samples, as the alkaline tartrate deteriorates on standing and the quantity of Cu_2O obtained in the blank increases.

Calculate as above for reducing sugars and report as per cent total sugars on a dry weight basis.

Tests for Starch

There are two methods of testing for starch: (1) the anthrone-sulfuric acid method and (2) the direct acid hydrolysis method.

Anthrone-Sulfuric Acid Method[7]

Equipment: Centrifuge, equipped with 50-milliliter head and tubes with pouring lips, adjustable speed to 1,200 rpm; magnetic stirrer and stirring fleas; metal disc holder, 8-place, for 22- by 175-millimeter test tubes to fit at 2-1. beaker; spectrophotometer; timer.

Reagents: Standard glucose solution. Stock solution: dissolve 100 milligrams of C.P. dextrose (anhydrous in 100 milliliters of water and preserve with 100 milligrams of sodium benzoate. Standard solution: dilute stock solution 1:100 (10 micrograms per milliliter) and use 5-milliliter portion for the standardization. Prepare standard solution daily.

Anthrone-sulfuric acid reagent: dissolve 500 milligrams of anthrone in 250 milligrams of cold 95 per cent sulfuric acid. Store at 0° C. and allow to stand at least 4 hours before use. Prepare fresh every 2 days; the reagent is unstable and gives high blanks and variable results when too old.

Ethyl alcohol, 80 per cent: dilute 1,680 milliliters of 95 per cent ethyl alcohol to 2 1. with water.

Perchloric acid, 52 per cent: add 217 milliliters of 60 per cent perchloric acid to 33 milliliters of water; store in a glass stoppered bottle.

Procedure: Weigh to fourth place approximately 200 milligrams of redried sample (indirectly from aluminum sample container) into a 50-milliliter centrifuge tube. Add a few drops of 80 per cent alcohol to wet the sample and prevent clumping. Add 5 milliliters of water and a stirring flea; stir thoroughly with magnetic stirrer. Add 25 milliliters of hot 80 per cent alcohol, stir thoroughly and after 5 minutes standing centrifuge at 1,200 rpm for 10 minutes. Aspirate and discard the alcoholic solution, taking care not to disturb the settled solids. Add 30 milliliters of hot 80 per cent alcohol, stir, centrifuge, and aspirate as before. Repeat this washing treatment until the alcohol solution gives a negative test for sugar with anthrone. Six or seven washings are usually necessary.

Add 5 milliliters of water to the residue after final centrifugation and stir on magnetic stirrer while adding 6.5 milliliters of 52 per cent perchloric acid. Stir for about 5 minutes and occasionally during the next 15 minutes. Add 20 milliliters of water and centrifuge. Pour the aqueous starch solution into a 100-milliliter volumetric flask. Add 5 milliliters of water and stir while adding 6.5 milliliters of 52 per cent perchloric acid. Solubilize as before for 30 minutes with occasional stirring and wash the entire contents of the tube into the 100-milliliter flask containing the first extract. Dilute the suspension to 100 milliliters and filter, using Whatman No. 1 paper, discarding the first 5 milliliters of solution.

Dilute 5 to 10 milliliters of the filtered starch solution with water to 100 milliliters or to contain 25 to 100 micrograms of starch per 5 milliliters of solution. Pipette 5 milliliters of the diluted solution into a 22 by 175 millimeter test tube, cool in ice water bath, and add 10 milliliters of chilled anthrone reagent down the sides of the tube. Swirl to mix the contents of each tube thoroughly while in the ice water bath and then transfer to a hot water bath and heat them together for 7.5 minutes at 100° C. (Suspending the tubes from an 8-place metal disc holder that fits a 2-1. beaker has proved to be satisfactory for mixing, heating, and cooling the solutions.) Cool the tubes rapidly to 25° C. in a water bath and determine the optical densities, using a spectrophotometer at 625 millimicrons. It is desirable to cover the tubes with aluminum foil after removing them from the cooling bath to prevent a turbidity, probably caused by moisture in the air. While the color is reputed to be stable up to 2 hours, prompt reading of the samples in the spectrophotometer seems desirable.

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[7] Adapted from *Analytical Chemistry,* 22 (Washington, D. C.: American Chemical Society), September, 1950, p. 1,156.

Prepare a daily standard curve using 0, 50, and 100 micrograms of glucose containing the same amounts of perchloric acid as that in the starch aliquots; use this calibration to obtain the yield of glucose from starch.

Calculation:

$$\frac{0.90\ (\text{microg. glucose } 2^{d} \text{ aliquot})}{10\ (\text{mg. init. dry wt. sample})}\ \frac{100}{(\text{ml. 1st. aliquot})}\ \frac{(\text{ml. } 2^{d} \text{ tot. vol})}{5} = \%\ \text{starch}$$

The factor 0.90 converts weight of glucose determined to weight of starch desired. The values 100 and 5 are milliliters in first total volume and in second aliquot, respectively.

Direct Acid Hydrolysis Method[8]

Equipment: Reflux condenser and 500-milliliter Erlenmeyer flask with $T_{/s}$ joint; magnetic stirrer and stirring bars.

Reagents: Hydrochloric acid, sp. gr. 1.125; ether (ethyl), C.P.: $18N$ sodium hydroxide.

Procedure: Weigh to nearest milligram approximately 4 grams of redried sample (indirectly from aluminum sample container) into a No. 1 filter paper in a funnel and rinse with five 10-milliliter portions of ether. Let ether evaporate and transfer residue to a 250-milliliter beaker. (Washing with ether is unnecessary if fat is not present.) Add 50 milliliters of cold water and stir for 1 hour with magnetic stirrer. Filter through No. 1 filter paper with suction, and rinse residue with about 250 milliliters of cold water. Transfer residue to a 500-milliliter $T_{/s}$ flask with 200 milliliters of water and add 20 milliliters of HCl. Fit flask with a cold finger condenser and reflux for 2.5 hours. (It is convenient to calibrate the flask at 200 and 250 milliliters.) Cool, nearly neutralize with NaOH and dilute to 250-milliliter volume with water. Filter through No. 52 and No. 42 filter papers together in filtering funnel. Take a suitable aliquot and determine dextrose as directed in the method for reducing sugars.

Calculation: (See calculations for per cent reducing sugars)

$$0.90\ [\%\ \text{reducing sugars (dextrose)}] = \%\ \text{starch}$$

Analysis by this method includes as starch the pentosans and other carbohydrates that undergo hydrolysis and are converted to reducing sugars on boiling with HCl.

TEST FOR CARBON

The induction furnace combustion method is a semi-micro method of estimating total carbon and has been found to be superior to the semi-micro wet combustion method. The samples are put in platinum crucibles and covered with alundum, and the crucibles and contents are placed in the field of a high frequency coil. The resistance of the crucible and contents to the rapidly changing magnetic field causes a rapid rise in temperature to more than 2,000° F. A jet of oxygen directed onto the sample insures immediate and complete oxidation; and the gases, carbon monoxide, and carbon dioxide pass through a catalyst furnace for conversion of the former gas to carbon dioxide. The gas stream is then passed into an absorption tube containing sodium hydroxide. The carbon dioxide is precipitated as barium carbonate, and this is collected on a Gooch crucible or filter paper.

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[8] A.O.A.C., *op cit.,* p. 374.

Equipment (including company catalog number): Induction furnace, Leco 1-H-10; oxygen valve, Leco 77-250; purifying train with rotometer, Leco 1150; dust trap, Leco 501-10; sulfur trap, Leco 6013; absorbent for sulfur trap, Leco 501-C, platinum crucibles, 10-15 milliliters, Fisher; gas absorption tube (see Figure A-2); Gooch crucibles; oxygen cylinder(standard commercial); pressure regulator (standard commercial).

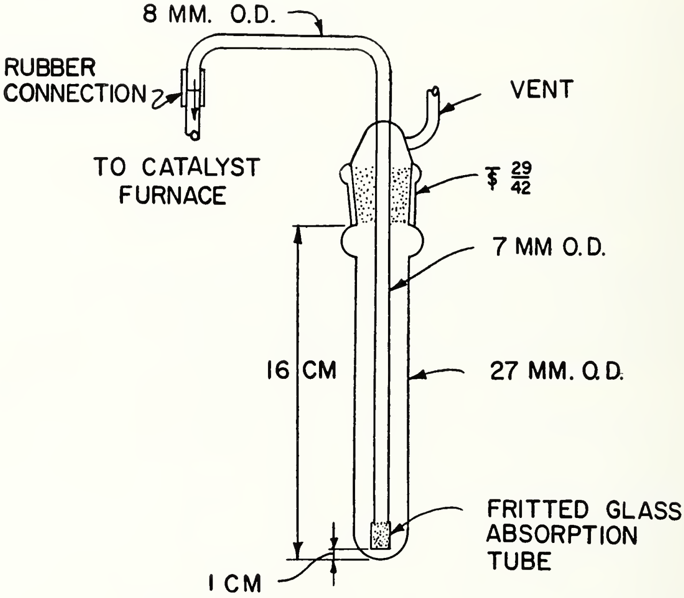

Fig. A-2. Gas absorption assembly.

Reagents: Alundum (granular 90 mesh), Fisher No. 7-689; sodium hydroxide 0.4*N* carbon dioxide free; ammonium hydroxide 0.4*N* carbon dioxide free; barium chloride 0.8*N* carbon dioxide free; filter paper (Whatman No. 52).

Procedure: Weigh 25 to 50 milligrams of redried sample directly into a 10- or 15-milliliter platinum crucible. (The sample weight should be great enough to yield 62.5 milligrams or more of $BaCO_3$ precipitate. Most organic materials sampled will yield 150 to 300 milligrams of $BaCO_3$.) Cover the sample with 90-mesh granular alundum, filling the crucible to within about ¼-inch of the top.

Before running the first sample, turn on the filament switch of the Leco induction furnace and allow the instrument to warm up for 15 minutes, then blank the train by placing an empty platinum crucible in the combustion chamber, and ignite for 15 minutes in a stream of oxygen flowing at 500 milliliters per minute. The instrument is now ready for the first sample.

Place the crucible on the ceramic pedestal of the induction furnace, and raise the crucible into the combustion chamber. The pedestal should be adjusted so that the crucible comes to rest in the center of the induction coil. Open the oxygen valve and adjust the flow rate to 500 milliliters per minute. Immediately measure 20 milliliters of 0.4*N* NaOH (CO_2-free) into the CO_2 absorption tube and connect it to the apparatus so that the gases from the furnace bubble into the solution through the fritted glass gas dispersion tube (Figure A-2). Set the grid tap switch at its highest setting and turn on the plate current. The crucible will reach its maximum temperature within 1 minute. After 15 minutes, remove the absorption tube, rinse the gas dispersion tube several times with distilled water, collecting the rinses in the absorption tube, and then transfer the contents into a 125-milliliter g.s. bottle; rinse several times with distilled water. (Always remove the absorption tube before turning off the oxygen to prevent the solution from backing up into the fritted glass tube.) Turn off the power and oxygen and remove the crucible. Crucibles may be cleaned with a small, stiff brush.

Precipitate the sample by adding 25 milliliters of $BaCl_2$-NH_4Cl solution (prepared by mixing 1 volume of 0.8*N* $BaCl_2$ and 4 volumes of 0.4*N* NH_4Cl) to the NaOH solution in the 125-milliliter g.s. bottle. Mix well and allow to digest at room temperature for 2 hours. Shake occasionally during this 2-hour period. The $BaCO_3$ is quantitatively filtered off in a tared Gooch or other suitable gravimetric filtering crucible using boiled distilled water as transfer and washing medium. Wash the precipitate with acetone, dry in an oven at 100° C. for 1 hour, cool in desiccator and weigh.

Calculation:

$$\frac{6.08\ (\text{net wt. } BaCO_3 \text{ ppt})}{(\text{net dry weight})} = \%\ \text{carbon}$$

The accuracy of this procedure for total carbon is highly dependent on maintaining consistently low blanks. Using weighed amounts of alundum is helpful and care to avoid contamination with atmospheric CO_2 during analysis is essential for accurate results. Reproducibility is well within 15 per cent with reasonable care.

While this method of total carbon assay is preferred to the wet combustion method, the cost of the induction furnace may prevent its use in many laboratories. The main disadvantage of the wet combustion method is that some materials are not completely oxidized and this is not always apparent, especially when dealing with biological materials.

The per cent of total carbon may be roughly calculated by dividing the per cent volatile solids by 1.8.

Calculation:

$$\frac{\%\ \text{volatile solids}}{1.8} = \%\ \text{carbon (approx.)}$$

Purdue University experiments indicate a factor of 2.08 (instead of 1.8), which applies *only* to the combustible portion of municipal refuse. Calculations from the Public Health Service laboratories in Savannah indicate a factor of 1.85 for relatively well sorted mixed refuse and for composts (separately calculated). Individual values for the factor ranged from 1.63 to 2.05.

TEST FOR NITROGEN (ORGANIC AND AMMONIACAL)

Kjeldahl-Wilfarth-Gunning Method

Equipment: Kjeldahl flasks for digestion and distillation, 800-milliliter; exhaust hood and special stack to outside for venting acid fumes during digestion; Kjeldahl connecting bulbs (use bulbs 5 to 6 centimeters in diameter, fit lower end with rubber stopper, and connect upper end to a condenser with rubber tubing); Erlenmeyer flasks, 500-milliliter.

Reagents:

Standard sulfuric acid, 0.1*N:* standardize by any official method.

Standard sodium hydroxide, 0.1*N:* standardize by titration against standard acid.

Sulfuric acid, 93 to 96 per cent H_2SO_4, free from nitrates and $(NH_4)_2SO_4$.

Mercuric oxide, reagent grade, free from nitrogen.

Sodium hydroxide-thiosulfate solution: dissolve 450 grams of NaOH, free from nitrates, in water and allow to cool; add 80 grams of $Na_2S_2O_3 \cdot 5H_2O$, keeping solution cool, and make to 1 l. with water.

Methyl red indicator: dissolve 1 gram of methyl red in 200 milliliters of 95 per cent ethyl alcohol.

Potassium sulfate, K_2SO_4.

Granulated zinc.

Procedure: Weigh to fourth place 0.7 to 2.5 grams of redried sample (indirectly from aluminum sample container) into a piece of Whatman No. 1 filter paper (9 centimeters). Fold paper and introduce into digestion flask. Add 15 to 18 grams of K_2SO_4, about 0.7 gram of mercuric oxide, and 25 milliliters of concentrated H_2SO_4. Heat gently until frothing ceases, then boil briskly, continuing digestion for a time after the mixture is colorless or nearly so—about 2 hours. Cool, add 200 milliliters of water, and dissolve cake. Add 1 gram of granulated zinc to prevent bumping and 75 milliliters of alkali-thiosulfate solution, pouring down the side of the flask so that it does not mix at once with the acid solution. Connect flask immediately to the condenser by means of the Kjeldahl connecting bulb, taking care that the tip of the condenser extends below the surface of the standard acid in the 500-milliliter flask, which acts as a receiver. Mix the contents by shaking and distill until all of the NH_3 has passed over into a measured quantity (usually 50 milliliters) of the standard acid. The first 150 milliliters of distillate usually contains all the NH_3. (It is helpful to mark the receiving flasks at about 200 milliliters and distill to the mark.) Titrate with standard alkali solution, using methyl red indicator.

A blank determination should be run with approximately 500 milligrams of cane sugar and with the same amount of standard acid to determine the nitrates that might be present in the reagents and reduced during digestion. A new blank value should be established when new reagents are used.

Calculations:

$$\text{(1) Blank: (ml. acid)-(ml. base)}\frac{\text{(norm. base)}}{\text{(norm. acid)}} = \text{ml. equiv. acid in blank}$$

$$\text{(2) Sample: (ml. acid)-(ml. base)}\ \frac{\text{(norm. base)}}{\text{(norm. acid)}} = \text{ml. equiv. acid in sample} + \text{blank}$$

(3) Sample corrected for blank: (2) — (1) = ml. equiv. acid in sample

$$(4)\ \frac{\text{(ml. equiv. acid in sample) (norm. acid) (14 mg.)}}{\text{10 (g. init. dry wt. sample)}} = \%\ \text{nitrogen}$$

The nitrogen measured is organic and ammoniacal and does not include the nitrite and nitrate nitrogen because the latter are not reduced to ammoniacal form during the analytical procedure. However, it is doubtful that many, if any, nitrites or nitrates would be formed in aerobic composting unless the stabilization period is greatly prolonged.

The following simplified calculation may be applied when the amounts of standard H_2SO_4 used for both blank and sample are exactly the same:

$$\frac{\text{[(ml. base blank) — (ml. base sample)] (norm. base) (14)}}{\text{10 (g. init. dry wt. sample)}} = \%\ \text{nitrogen}$$

TEST FOR PROTEIN

The protein content may be roughly estimated by multiplying the nitrogen (organic and ammoniacal) content by 6.25.

Calculation:

$$6.25\ (\%\ \text{nitrogen}) = \%\ \text{protein (approx.)}$$

TEST FOR CARBON-NITROGEN RATIO

The carbon-nitrogen ratio (C/N) is of interest in composting and in composts, sludges, and other humus containing materials applied to the soil.

Calculation:

$$\frac{\%\ \text{carbon}}{\%\ \text{nitrogen}} = \text{carbon-nitrogen ratio}$$

In the United States, total carbon and nitrogen contents—the latter approximated by the organic and ammoniacal nitrogen analysis—are usually used in computing C/N. In Europe, the trend is to use only the available carbon and nitrogen contents. These are generally determined as water-soluble C and N, which eliminates much of the organic C and N in such materials as wood, coal and coke, paper, stalks, and leaves. However, in time decomposition in the soil will gradually make much of the organic C and N available to plants, and this refinement in C/N calculation is debatable.

TEST FOR PHOSPHORUS (PHOSPHATE)

Equipment: Kjeldahl flasks for digestion, 800-milliliter; fume wood; volumetric flasks, 200-milliliter; aluminum sample containers (2-inch diameter by ⅞-inch); spectrophotometer, photoelectric colorimeter (equipped with a light filter with maximum transmittance near 625 to 675 millimicrons, or visual colorimeter; drying oven, desiccator, analytical balance, and columetric pipettes.

Reagents:

Sulfuric acid, 93 to 96 per cent H_2SO_4.
Sodium hydroxide, 10*N* (40 per cent).

Ammonium molybdate solution: dissolve 5 grams of $(NH_4)_2$ Mo 04 in 1 l. of 0.75*N* HCl.

Elon solution: dissolve 10 grams of elon in 1 l. of 3 per cent $NaHSO_3$.

Standard potassium dihydrogen phosphate solution: dissolve 1.917 grams of pure dry KH_2PO_4 in water and dilute to 1 l. One milliliter of this solution is equivalent to 1 milligram of P_2O_5.

Procedure: Weigh about 3 grams of redried sample in previously dried and tared sample container. (It is best to do the redrying at 75° C. for two hours after transfer into the sample container.) Transfer the sample to a Kjeldahl flask and add about 25 milliliters of concentrated H_2SO_4 and a few boiling beads. Digest under fume hood until the liquor becomes straw colored, indicating that the organic matter is destroyed. Cool, rinse into a 200-milliliter volumetric flask (except for the beads), and add about 80 milliliters of water. Make alkaline with the NaOH solution, using phenolphthalein indicator until the solution just turns pink. Make up to the mark with water and mix thoroughly. Filter, discarding the first portion of the filtrate, retaining the solution for determination of both phosphate and potash. (Basic sample solution volume is 200 milliliters.)

Pipette 10 milliliters of the above solution into a 100-milliliter beaker, add 30 milliliters of ammonium molybdate solution and 10 milliliters of elon solution (50 milliliters total volume). At the same time, pipette measured portions of standard phosphate solution into 50-milliliter volumetric flasks, add the same amounts of ammonium molybdate and elon solutions, and dilute to the mark with water. Mix sample and standards thoroughly and allow to stand 30 minutes. (It is suggested that standards of 1, 2, 4, 6, 8, and 10 milligrams of P_2O_5 in 50 milliliters be used for comparison or to prepare calibration curve for spectrophotometer or photoelectric colorimeter.) Read or compare sample immediately in colorimeter.

Calculation:

$$\frac{\text{mg. of } P_2O_5 \text{ (colorimetric determination)} \times 2}{\text{g. net dry weight}} = \%\ P_2O_5$$

(This calculation is for an aliquot of 10 milliliters from the 200-milliliter prepared sample solution and must be adjusted if amounts are varied.)

TESTS FOR POTASSIUM (POTASH)

There are two methods of testing for potassium: (1) the flame photometric method and (2) the sodium tetraphenyl borate method.

Flame Photometric Method[9]

Equipment: Spectrophotometer with flame photometer attachment.

Reagents: Standard potassium chloride solution: dissolve 1.584 grams of dry reagent grade KCl in H_2O and dilute to 1 l. One milliliter of this solution is equivalent to 1 milligram of K_2O.

Procedure: Prepare a series of standards ranging from 10 to 100 parts per million K_2O (1 to 10 milliliters KCl solution diluted to 100 milliliters).

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[9] Spain, J. M., and White, J. L., "Procedure for the Determination of Phosphorus and Potassium in Soil Samples." Special Bulletin, Soils Testing Laboratory (Lafayette, Ind.: Purdue University, March, 1960).

The solution prepared for the phosphorus determination is used for the determination of potassium by means of the spectrophotometer. Operate the instrument in accordance with the instructions of the manufacturer. Allow instrument to reach operating equilibrium before use. Atomize portions of the standards toward the end of the warm-up period until reproducible readings for the series are obtained.

Run standards, covering the K_2O range of the samples involved at frequent intervals during atomization of series of sample solutions. Repeat this operation with both standard and sample solutions a sufficient number of times, depending on the precision desired, to result in reliable average readings for each sample solution.

Prepare a standardization curve of concentration (ppm) of potassium as K_2O versus optical density from the KCl standards.

Determine concentration of K_2O in sample solutions from the standardization curve.

Calculation:

$$\frac{\text{ppm of } K_2O \text{ in sample solution}}{50 \times (\text{g. net dry weight})} = \%\ K_2O$$

(If sample solution is above the range of the standards, dilute a portion of the solution so that it will be within the range and adjust the calculation. The formula above is for a basic sample solution volume of 200 milliliters and must be adjusted if volume is varied.)

Sodium Tetraphenyl Borate Method[10, 11]

Equipment: Fritted glass crucible; drying oven; desiccator; analytical balance.

Reagents:

Sodium tetraphenyl boron solution: dissolve 23 grams of $(C_6H_5)_4BNa$ in about 800 milliliters of water. Add 20 to 25 grams of reagent grade $Al(OH)_3$, stir for 10 minutes and filter, collecting the first 100 milliliters of filtrate separately for refiltration. Dilute the clear filtrate to 1 l.

Ethylene diamine tetra acetic acid (EDTA) solution: dissolve 40 grams of the disodium salt of the above acid in distilled water and make up to 1 l.

Sodium hydroxide solution, 40 per cent NaOH.

Wash solution: add 0.10 grams of $(C_6H_5)_4BNa$ to 900 milliliters of water. Stir occasionally for 30 minutes; add 5 grams of $Al(OH)_3$, stir for 5 minutes and filter; dilute filtrate to 1 l.

Ammonium carbonate $(NH_4)_2CO_3$.

Formaldehyde, 36 per cent.

Procedure: Transfer 25 to 50 milliliters aliquot of sample solution as prepared under procedure for phosphorus to a 250-milliliter beaker. Make slightly alkaline with $(NH_4)_2CO_3$. Filter if necessary. Add 10 to 25 milliliters of EDTA solution, 5 to 10 milliliters of 36 per cent formaldehyde, 2 to 5 milliliters of 40 per cent NaOH, and 100 milliliters of water. Slowly, while stirring, add 1 milliliter of sodium tetraphenyl boron solution for each 2

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[10] *Loc. cit.*

[11] Purdue University, "Determination of Potassium in Fertilizer by the Sodium-Tetra-Phenyl-Borate Method." Special Bulletin, Department of Agriculture (Lafayette, Ind.: Purdue University, 1957).

milligrams of K_2O expected in the sample, plus an additional 10 milliliters to provide an excess. Let stand for 5 to 10 minutes and filter through a previously dried and tared fritted glass crucible. Wash final traces of precipitate with 5-milliliter portions of wash solution in transferring from beaker to crucible. Wash bulk of the precipitate in the crucible using a total of 50 milliliters of wash solution. Wash the precipitate with 5 milliliters of distilled water, dry at 110° C., cool in desiccator, and weigh.

Dissolve precipitate in acetone, rinse the crucible with distilled water, dry, cool in desiccator, and reweigh. Run a blank on reagents.

Calculation:

$$\frac{(\text{wt. of ppt.-wt. blank}) \times 13.143}{\text{wt. of sample, g.}} \times \frac{200}{(\text{ml. aliquot})} = \%\ K_2O$$

Test for Hydrogen-Ion Concentration (pH)

Equipment: Potentiometer (pH meter) with glass-calomel electrode system.

Reagents:

CO_2-free distilled water: boil distilled water, pour while boiling into Pyrex carboy or siphon bottle and immediately insert stopper through which siphon and air inlet tube protrude; immediately connect a CO_2-absorbing tube to air inlet tube, the absorber containing soda lime (4-8 mesh), ascarite, or similar CO_2 absorber.

Buffer solution, concentrated, pH7: dilute as directed on label and use to standardize potentiometer for each series of determinations.

Procedure: Use fresh sample collected immediately after preliminary grinding, preferably at the same time and from the same materials as samples collected for moisture determination. For partially decomposed materials (in piles, bins or cells, pits, or windrows) the pH may vary greatly with depth, so samples should be related to it. To indicate over-all pH value for the mass, samples should be taken immediately after thorough mixing, grinding, or regrinding. Size of individual samples and number of replicates are dependent on particle size and uniformity of materials. For materials prepared as recommended under "Initial Sampling" use of a 100-milliliter beaker ⅓ to ½ full of loose sample should be adequate.

If sample is semifluid or fluid, stir and determine pH directly. If not, add an equal volume of CO_2-free distilled water and stir (a glass rod fitted with rubber or neoprene policeman is recommended). Determine pH according to instructions by the manufacturer of the potentiometer used. Avoid contact between electrodes and glass beaker. Check pH meter before and after use against diluted buffer solution. Rinse both electrodes and stirrer with CO_2-free water (a polyethylene washing bottle is recommended) and wipe with disposable cleaning tissue after each determination and standardization check. Report pH to nearest 0.1.

Test for Gross Calorific Value

Equipment: Parr oxygen bomb calorimeter, Series 1300 (isothermal jacket); Parr oxygen filling connection, Series 1823; oxygen cylinder (standard commercial); trip balance, net capacity 3,000 to 5,000 grams; pressure regulator (standard commercial); drying oven; desiccator; analytical balance.

Reagents:

Distilled water.

Sodium carbonate solution, 0.0725*N*.: dissolve 3.84 grams of NA_2CO_3 in distilled water and dilute to 1 liter; sodium hydroxide or potassium hydroxide solutions of the same normality are acceptable.

Methyl orange or methyl red indicator.

Procedure: Attach a single length of 10 centimeters of standard fuse wire between the electrodes of the oxygen bomb head.

Weigh 0.8 to 1.2 grams (never more than 1.5 grams) of the redried sample directly into a metal combustion capsule. Place the capsule in the loop holder on the bomb head. Bend the center of the fuse wire down so that it is set slightly above the surface of the material in the capsule.

Put 1 milliliter of water in the bomb from a pipette; put the bomb head into the cylinder; place contact ring above the sealing gasket; screw the cap down firmly by hand.

Attach the filling connection to the bomb inlet valve and slowly admit oxygen to 30 atmospheres gage pressure at room temperature. (If too much oxygen should accidently be introduced, do not proceed with the combustion; exhaust the bomb.)

Fill the calorimeter bucket with 2,000 grams (plus or minus 0.5 grams) of distilled water, which may be measured volumetrically instead of by weighing if it is always done at the same temperature. The temperature of the water should be 3° to 4° F. below that of the room.

Set the filled bucket in the calorimeter jacket; grasp the bomb valve between the thumb and the forefinger, and lower the bomb into the water, taking care to avoid jarring or disturbing the contents. Attach the thrust terminal to the bomb electrode and shake back into the bucket all drops of water adhering to the fingers.

Place the cover on the jacket with the thermometer toward the operator. Lower the cover into position, using care to avoid striking the thermometer against anything. Put on the rubber drive belt and start the motor. The stirrer will turn at the proper speed if the electric supply to the motor corresponds to that stamped on the Parr motor nameplate. If any other drive motor is used, adjust the stirrer to 150 clockwise revolutions per minute.

Run the motor for 5 minutes to attain thermal equilibrium, but do not record temperatures during this period. Adjust the thermometer reading lens and be prepared to take temperature readings as soon as equilibrium is indicated by a slow, uniform rise.

Read and record the calorimeter temperature to the nearest 0.01° F. at 1-minute intervals for exactly 5 minutes. Then press the button on the ignition unit to fire the charge at the start of the sixth minute, recording the exact time and temperature at the firing point.

Record temperature readings (taken without magnifier) at 45, 60, 75, 90, and 105 seconds after firing. After the period of rapid rise (about 4 or 5 minutes after firing) adjust the reading lens and record temperatures to the nearest 0.01° F. at 1-minute intervals until the difference between successive readings has been constant for 5 minutes. Usually the temperature will reach a maximum, then drop slowly.

The net rise is equal to the difference between the initial temperature at the time of firing and the final maximum temperature developed in the calorimeter. Take 60 per cent of this net rise and add it to the observed temperature at the firing point. By interpolation, calculate the time at which the thermometer had reached this temperature.

After completing the readings, stop the motor, remove the belt, and lift the cover from the jacket; wipe the thermometer bulb with a clean cloth to remove any water, and set the cover on the support stand; disconnect the firing connection from the bomb terminal, and lift the bucket and bomb out of the jacket.

Lift the bomb out of the bucket and relieve all residual pressure.

After all pressure has been relieved, remove the screw cap, lift out the bomb head, and place it on the support stand. Examine the interior of the bomb for soot or other evidence of incomplete combustion, and discard the test if any is found.

Wash all interior surfaces of the bomb with a jet of distilled water and quantitatively collect the washings in a beaker. Titrate with 0.075*N* alkali solution, using methyl orange or methyl red. Save the solution remaining after titration for determining the sulfur content of the sample.

Carefully remove all unburned pieces of fuse wire from the bomb electrodes, straighten them, and measure their combined length in centimeters. Subtract this length from the initial 10 centimeters, and enter this value on the data sheet as the net amount of wire burned.

Calculations: The following data should be available at the completion of a test in the plain calorimeter:

a = time of firing.
b = time (nearest 0.1 minute) when the temperature reaches 60 per cent of the net rise.
c = time at beginning of period (after the temperature rise) in which the rate of temperature change has become constant.
t_a = temperature at time of firing.
t_c = temperature at time.
r_1 = rate at which temperature was rising during the 5-minute period before firing (degrees F. per minute).
r_2 = rate at which the temperature was falling during the 5-minute period after time c (degrees F. per minute). If the temperature was rising instead of falling after time c, subtract the quantity r_2 (c-b) instead of adding it when computing the corrected temperature rise.
c_1 = milliliters of 0.075*N* alkali solution used in the acid titration.
c_2 = percentage of sulfur in the sample.
c_3 = centimeters of fuse wire consumed in firing.
W = energy equivalent of the calorimeter (supplied by the manufacturer) in calories per degree Fahrenheit.
m = mass of sample in grams.
$t = t_c - t_a - r_1(b-a) + r_2(c-b)$.
$e_1 = c_1$ if 0.0725 N alkali was used for titration.
$e_2 = (14)\ (c_2)\ (m)$.
$e_3 = (2.3)\ (c_3)$ when using Parr 45C10 nickel-chromium fuse wire, or
$= (2.7)\ (c_3)$ when using No. 34 B.&S. gage iron fuse wire.
H_g = gross calorific value

$$H_g = \frac{tW - e_1 - e_2 - e_3}{m}, \text{ calories per gram}$$

Calories per gram (1.8) = B.T.U. per pound

TEST FOR NET CALORIFIC VALUE

Net calorific value is calculated from the gross calorific value by making a deduction of 1,030 B.T.U. per pound of water derived from a unit quantity of the material, including both the water originally present as moisture and that formed by combustion.

Calculations:

$$H_n = \text{net calorific value}$$

$$H_n = H_g - 10.30\ (H \times 9),\ \text{B.T.U. per pound}$$

where,

$$H_g = \text{gross calorific value, B.T.U. per lb.}$$

$$H = \text{total \% hydrogen in the material, \%.}$$

TEST FOR SULFUR[12]

Equipment: Parr oxygen bomb calorimeter, Series 1300; or Parr oxygen bomb sulfur apparatus, Series 1900; oxygen cylinder (standard commercial); pressure regulator (standard commercial); steam bath or hot plate; crucible; muffle furnace (600° to 900° C.); drying oven; desiccator; analytical balance; beakers, filter paper (ashless); watch glass; and volumetric pipettes.

Reagents: Wash water, 1 milliliter saturated solution of methyl orange indicator per liter of distilled water; ammonium hydroxide, concentrated; hydrochloric acid, concentrated; bromine solution, saturated; barium chloride solution (10 per cent).

Procedure: Collect the bomb washings following the combustion of a sample weighing not more than 1 gram. If this sample has not been used for a calorimetric test, allow the bomb to stand in the water bath at least 10 minutes after firing.

Release the residual gases slowly and at an even rate so that the pressure is reduced to atmospheric in not less than 1 minute.

Open the bomb and wash all parts of its interior, including the combustion capsule, valve passages, and electrodes, with a fine jet of wash water. Wash until no acid reaction is observed, collecting the washings in a beaker. Be sure to transfer any precipitate from the bomb or capsule to the beaker.

If a calorimetric test has been made, titrate the washings with standard sodium carbonate solution to determine the acid correction. After neutralizing the solution, add 1 milliliter of ammonium hydroxide, heat the solution to boiling, and filter through a rapid filter paper. Wash the residue and filter paper with hot distilled water and add sufficient water to bring the total volume of solution to approximately 250 milliliters. Neutralize with concentrated hydrochloric acid and add 2 milliliters in excess.

Add 10 milliliters of saturated bromine water and evaporate to approximately 200 milliliters on a hot plate or other source of heat. Adjust to a slow boil and stir constantly while adding 10 milliliters of a 10 per cent barium chloride solution from a pipette.

Continue stirring for 2 minutes, cover with a fluted watch glass and keep just below boiling on a steam bath or hot plate until the volume is reduced to 75 milliliters, then allow the precipitate to settle for another hour while cooling; filter through an ashless filter paper, and wash with warm water until free from chlorides.

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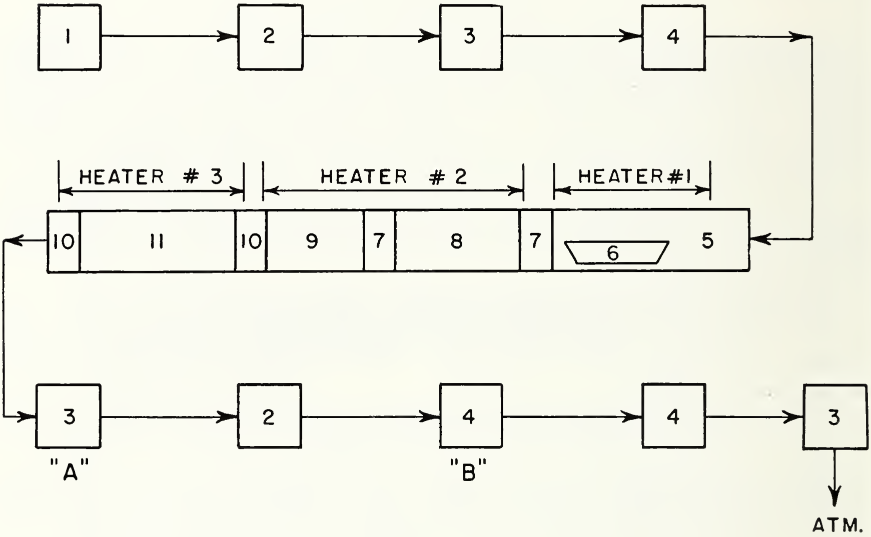
[12] Parr Instrument Co., "Oxygen Bomb Calorimetry and Combustion Methods," Technical Manual No. 130 (Moline, Ill.: The Company, 1960).

Transfer the paper and precipitate to a weighed crucible, dry at low heat, char the paper without flaming, then raise the temperature to a good red heat (approximately 800° C.) and heat to constant weight.

After ignition is complete, allow the crucible to cool to room temperature (final cooling in a desiccator) and weigh.

Calculation: Determine the exact weight of the barium sulfate precipitate and calculate the percentage of sulfur in the sample as follows:

$$\text{Sulfur, \%} = \frac{\text{wt. BaSO}_4 \times 13.734}{\text{wt. sample}}$$



1 - OXYGEN CYLINDER

2 - GAS WASHER WITH CONCENTRATED SULFURIC ACID

3 - DRYING TUBE WITH MAGNESIUM PERCHLORATE

4 - DRYING TUBE WITH ASCARITE

5 - COMBUSTION TUBE

6 - COMBUSTION BOAT

7 - ASBESTOS FIBER PLUG

8 - LEAD CHROMATE

9 - CUPRIC OXIDE

10 - SILVER WIRE (TWISTED INTO A MAT)

11 - LEAD PEROXIDE (MAINTAINED AT 190 °C)

Fig. A-3. Combustion train assembly.

TEST FOR HYDROGEN AND CARBON

Equipment: Electrically heated organic combustion furnace, Fisher No. 10-474; combustion tube, Fisher No. 10-474-15; combustion boats and covers, Fisher No. 7-651; drying tubes, U-shape, with side tubes, I.D. 16 milliliters, height 150 millimeters; Fisher-Milligan gas washers, Fisher No. 7-513; analytical balance; drying oven, desiccator, and tygon tubing (or like); oxygen cylinder (standard commercial).

Reagents: Sulfuric acid, concentrated; cupric oxide, granular; lead chromate, fused; lead peroxide, granular; magnesium perchlorate; ascarite, 8-20 mesh; silver wire; asbestos fiber.

Procedure: Assemble combustion train as indicated in Figure A-3. Item 10 of the train is used to help conduct the heat from the center of the combustion tube to the exit so that no moisture collects in this part of the tube. The lead peroxide (item 11) should be maintained at 190° C. throughout the entire test. Obtain initial weight of items "A" and "B." Weigh 0.5 to 1 gram of the redried sample directly into a combustion boat. Place the cover on the boat and put it into the end of the combustion tube. Turn on heaters No. 1 and No. 2 and gradually increase the temperature to approximately 800° to 900° C. Regulate the flow of oxygen through the combustion train at approximately 500 milliliters per minute. Allow the sample to combust for at least 30 minutes, and then allow enough time to insure that all of the water formed during combustion has been driven (carried by the oxygen flow) into the drying tube containing the magnesium perchlorate.

Obtain final weight of items "A" and "B."

Calculations:

$$\%\ \text{hydrogen} = \frac{\text{increase in weight of “A”} \times 11.17}{\text{sample weight}}$$

$$\%\ \text{carbon} = \frac{\text{increase in weight of “B”} \times 27.27}{\text{sample weight}}$$

A method for the determination of carbon and hydrogen developed at Purdue University for the combustible portion of refuse only is:

$\%\ C = \%\ \text{volatile matter}/2.08$ $\qquad$ $\%\ H = \%\ \text{volatile matter}/15.0$

REFERENCES — APPENDIX A

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Appendix B

ORDINANCE PROVISIONS FOR REFUSE DISPOSAL

Typical provisions in municipal ordinances for regulating the disposal of refuse are presented here as a guide to local officials in developing a new ordinance or revising an old one. Ordinances are not reproduced in their entirety because it is most improbable that any two cities are confronted with all of the same local conditions and therefore need all of the same provisions.

The ordinance provisions quoted have proved satisfactory in the city in which they are in force. They are not necessarily the best ones possible, and changing local conditions sometimes require changes in what once were satisfactory provisions.

The subjects ordinarily covered by disposal provisions of a refuse removal ordinance can be grouped under the following headings:

1. Definitions
2. Responsibility for refuse disposal
3. Management of disposal facilities
   - A. Designation of authorized sites and facilities
   - B. Who may use disposal sites
   - C. Responsibility of site users
   - D. Salvage
4. Control of kinds of refuse disposed of at municipal facilities
   - A. Separation of refuse
   - B. Hazardous refuse
   - C. Dead animals
5. Control of private disposal sites
6. On-site disposal
7. Air pollution controls
8. Financing
9. Penalties for violations; severability

DEFINITIONS

The terms used to designate different kinds and classes of refuse and technicalities should be defined in the ordinance. Standard definitions should be used in the ordinance, and in all published rules, notices, instructions, and publicity material. Definitions are given in Chapter 1.

The application of definitions to local needs is illustrated in the refuse collection and disposal ordinance for Rochester, New York:

> 11.1-2. Definitions. For the purpose of this ordinance, the following terms shall have the meanings ascribed to them in this section unless different meanings are clearly indicated by the context.
>
> (a) Department shall mean the Department of Public Works of the City of Rochester.
>
> (b) Commissioner shall mean the Commissioner of Public Works of the City of Rochester.
>
> . . . .

(h) Garbage shall mean all putrescible animal or vegetable wastes resulting from the handling, preparation, cooking and consumption of food in any private dwelling house, multiple dwelling, hotel, restaurant, building, or institution.

(i) Rubbish shall mean all cardboard, plastic, metal, or glass food containers, waste paper, rags, sweepings, small pieces of wood, excelsior, rubber, leather, and similar waste materials that ordinarily accumulate around a home, business or industry. It shall not include garbage, ashes, bulk refuse, dead animals, hazardous refuse, industrial waste or building waste resulting from the operations of a contractor.

(j) Mixed refuse shall mean garbage and rubbish placed and stored together in a standard refuse container or in a substitute refuse container as required by this ordinance.

(k) Ashes shall mean the residue of the combustion of solid fuels.

(l) Bulk refuse shall mean discarded household furniture, beddings and mattresses, leaves, lawn cuttings, tree trimmings and hedge trimmings.

(m) Dead animals shall mean animals that have died naturally or have been accidentally killed. Animals or parts of animals from slaughter houses are not included in this category.

(n) Hazardous refuse shall mean any refuse the handling or disposal of which, in the opinion of the commissioner, would constitute a danger to city employees or to city property.

(o) Household waste shall mean mixed refuse, ashes and bulk refuse originating in and around private dwellings, multiple dwellings, fraternity houses, living quarters or dining facilities located in schools, colleges or universities.

(p) Institutional waste shall mean mixed refuse and ashes originating in and around tax exempt hospitals and public, charitable, philanthropic or religious institutions conducted for the benefit of the public or a recognized section of the public. Institutions not covered by the foregoing definition shall be considered commercial establishments.

(q) Commercial waste shall mean rubbish, mixed refuse, and ashes originating in and around commercial establishments, industrial establishments, hotels, restaurants, cafeterias and nonpublic institutions.

(r) Industrial waste shall mean any and all residue resulting directly from industrial or manufacturing operations. It shall not include waste originating from commercial operations of an industrial establishment, nor shall it include waste resulting from the commercial operations of persons, firms or corporations engaged in the construction of buildings, the repairing of streets and buildings, demolition or excavation. Residue or waste resulting from tree or landscaping services shall also be excluded.

(s) Building waste shall mean any and all refuse or residue resulting directly from building construction, reconstruction, repair, or demolition; from grading, shrubbing, or other incidental work in connection with any premises; or from replacement of building equipment or appliances.

(t) A licensed waste collector shall mean any person, firm, or corporation who obtains a license from the Commissioner of Public Works to collect or transport public or private household waste,

> institutional waste, industrial or commercial wastes, regardless of the place of origin, over the streets of the city.
>
> (u) Building debris shall mean any refuse or residue resulting from minor noncommercial repairs to a private dwelling made by the owner or occupant himself.

Where feeding garbage to hogs is a method of disposal the term swill is often defined the way Sacramento County, California, has done it:

> Section 3(e) "Swill" shall mean that particular garbage which is wholly or nearly . . . edible and salable as food and having food value for animals or fowl, accumulating from animal, vegetable, or other waste material from clubs, hospitals, hotels, restaurants, homes and other dwelling places, and from public eating places.

In some cities where refuse is incinerated, combustible and noncombustible refuse are specifically defined. The Hartford, Connecticut, ordinance designates these types of refuse as follows:

> Sec. 18-1 (a-2) The term "incinerator refuse" as used in this chapter shall mean plastic, metal and glass food containers, dust, sweepings, waste paper, rags, wood, excelsior, bedding, rubber, leather, rubbish, leaves, brush, small dead animals and birds and similar waste materials that ordinarily accumulate in and around a home or business, except building materials and portions of trees greater than six inches in diameter.
>
> (b-1) The term "non-combustible" refuse as used in this chapter shall mean ashes, cans, bottles (other than food containers), earth, wire, glass, heavy metal, automobile parts, broken kitchen ware, mattresses and other materials of like nature.

Responsibility for Refuse Disposal

It is customary to designate in the refuse disposal ordinance the officer, department, or agency responsible for carrying out the provisions. Frequently the authority is clearly set forth in administrative codes or in separate ordinances but if there is any question as to the allocation of authority, powers, and duties, it should be spelled out. In Eugene, Oregon, supervision of disposal is the responsibility of the city manager and a garbage board:

> Section 2. The regulation of the disposal and hauling of garbage in the City of Eugene shall be under the supervision of the City Manager; provided, however, the City Manager may appoint a Garbage Board consisting of three (3) members residing in the City of Eugene, and designating its powers and duties for the administration of this Ordinance. Said powers and duties shall not be inconsistent with the provisions of this Ordinance and shall include, but not be limited to, authority to conduct periodic inspections to insure full compliance with the terms and provisions of this Ordinance. . . .

The Board of Public Works is responsible for disposal of refuse in Waterbury, Connecticut:

> I. Responsibility. The Board of Public Works of the City of Waterbury shall have power and is hereby empowered to take such measures as they shall deem effectual for the removal and disposal of refuse from the City of Waterbury or any portion thereof; under the following rules and regulations. . . .

The city council issues permits for refuse disposal in Somerset, Kentucky:

> Section III, I. Permits.– No person, firm or corporation shall collect, transport, or dispose of garbage or refuse within the city limits who does not possess a permit, said permit shall be issued only by the City Council and approved by the Mayor or his designated representative, and only upon the payment of any annual permit fee which is to be set by the City Council and only after the Mayor has satisfied himself that the licensee is capable of complying with the requirements of this code. The permit may be revoked when deemed necessary to the public welfare by the Mayor or upon recommendation of the City Council.

Specific powers to regulate and direct users of the Albert Lea, Minnesota, sanitary landfill are included in that city's ordinance:

> Section 6, 6.1. All garbage and other refuse shall be delivered and deposited for disposal on the sanitary landfill area in accord with the directions and orders of the city's representative in charge of operations.

Enforcement of the Manitowoc, Wisconsin, refuse ordinance is the responsibility of the city health commissioner with the assistance of the police and street commissioners:

> 13.06 (7) City Health Commissioner to Enforce Provisions of This Section. Duty of Police and Street Commissioners. It shall be the duty of the City Health Commissioner to strictly enforce the provisions of this Section and to see that any and all violations thereof are promptly abated and the violators prosecuted, and it shall be the special duty of the Chief of Police, Street Commissioner, and all policemen to give attention throughout the city to any and every case of violation of this Section and to promptly report to the City Health Commissioner, in writing, every such violation which shall come to their knowledge.

Management of Disposal Facilities

Designation of Authorized Disposal Sites and Facilities

The elimination of unauthorized and promiscuous disposal of refuse is basic to an effective sanitation program. It is customary, therefore, to restrict disposal as it is in Omaha, Nebraska:

> Section 19-4A.7–III Disposal of Refuse. No person shall throw, drop, or deposit, or cause to be thrown, dropped, or deposited on any premises or vacant property in the City any waste (including, but not limited to, garbage, ashes, rubbish, building rubbish, dead animals, putrescible matter, and anything injurious to health), provided, however, that the prohibition contained in this paragraph shall not apply to the deposit of wastes not injurious to health on a public site where permission to make such a deposit is granted by the Sanitation Commission of the City of Omaha, nor to the filling in or grading of property with earth, mud, ashes, and similar materials. . . .

The Salt Lake City, Utah, ordinance is similar, but it also refers to the control of farms on which hogs are fed garbage and to trade wastes:

> Sec. 18-3-6–Disposition of garbage and waste. It shall be unlawful for any person to deposit or cause or permit to be deposited any

> garbage, market waste, stove waste, trade waste, or any other similar refuse in or upon any street or alley, or upon any premises in Salt Lake City without express permission from the board of health. The board of health may give permit for the feeding of garbage or swill upon premises properly equipped and maintained so as to prevent the creation of a nuisance, or for the depositing of ashes and other dry material for filling purposes, or for health [purposes] may designate and under such restriction as said board may impose, or for the assorting, baling, and marketing of trade waste upon premises properly equipped and maintained.

Deposit of refuse in or around bodies of water is specifically prohibited in Knoxville, Tennessee:

> Section 14: [from code supplement]. Depositing in streams, ponds, etc. It shall be unlawful for any person to throw, discard, deposit, dispose of, or allow any trash, garbage waste, scraps of food, vegetables, fruits, meat, industrial or processed waste, or the like into, about, around, or near any stream or body of water, regardless of size, within the confines of the city.
>
> This section shall not be construed to prohibit people from feeding ducks, swans, fish, and like aquatic creatures within reasonable bounds as the need may require.

Who May Use Disposal Sites

Restriction of the use of disposal sites or facilities to designated individuals or establishments located within certain governmental boundaries is common practice. In Rochester, New York, refuse disposed of at the municipal incinerator or landfill is restricted to that originating within the city; and certification of this fact is required:

> 11.1-16. Disposal of Refuse. Acceptable rubbish and mixed refuse and household or commercial ashes and unburnables originating within the city and transported to a designated city-operated incinerator or city-operated landfill by any person shall be accepted by the department for disposal during designated hours of operation. All persons offering such acceptable rubbish and mixed refuse or household or commercial ashes and unburnables for disposal, shall, in each instance, submit proof of the origin of the said rubbish and mixed refuse, in the form of a certificate certifying ownership that the said material originated within the city and requesting disposal.

Provision is made in the Rochester, New York, ordinance, however, for contracts for disposal of wastes from cities within the county and from industrial establishments:

> 11.1-17. Contracts for Disposal of Wastes. Contracts between the City of Rochester and a town or other municipality within the County of Monroe for the disposal of wastes originating within the town or municipality, as authorized by 11.1-1 hereof, shall be limited to the disposal in city-owned and operated incinerator plants of garbage and mixed refuse as defined in this chapter. Use of city landfill areas for such disposal is expressly prohibited.
>
> Contracts between the City of Rochester and an industrial establishment for the disposal of acceptable industrial wastes originating within the city, as authorized by 11.1-1 hereof, may provide for such disposal

> in city landfill areas or in city-owned and operated incinerators of acceptable industrial wastes, as defined in this chapter.

A contractor who collects refuse in Santa Clara, California, may be authorized by the board of trustees to use the municipal disposal site:

> Section 12. For the collection, removal and disposal of the refuse, garbage and waste matter in the City of Santa Clara in the manner in this ordinance provided, a contract for a period not to exceed five (5) years may be entered into by the City of Santa Clara, in accordance with, and subject to the terms of this ordinance.
>
> Said contract may or may not provide that the said Scavenger may have the use of the municipal dump for the dumping of garbage, waste matter or refuse, and further that the City may or may not upon reasonable notice terminate the right to such use of said municipal dump, and require all garbage, waste matter and refuse to be disposed of elsewhere than said dump. Said contract shall provide further that the Scavenger, while being allowed the use of said dump, shall keep the same in good order and condition, and to the satisfaction of the Health Officer, or other officer which the Board of Trustees of said City may from time to time designate, and that said Scavenger shall incinerate any matter required to be incinerated, to the satisfaction of the Health Officer. Said contract may or may not provide that any matter collected outside of the City of Santa Clara shall be disposed of in said municipal dump.

In Washington, D. C., no charge is made for disposal at city incinerators and landfills, but no refuse from outside the district can be disposed of at them:

> Sec. 29. The incinerators and landfills operated and maintained by the Division of Sanitation of the government of the District of Columbia shall be for the disposal of refuse produced within the boundaries of the District of Columbia. No person, firm or corporation shall be permitted to deposit at any such incinerator or landfill any refuse which has been produced outside of the District of Columbia, and any person delivering refuse produced outside the District to same, or, in the event such refuse may have been unloaded at such incinerator or landfill, such person shall be required to remove such refuse immediately.

Responsibility of Site Users

Many cities control the actions of users of refuse disposal facilities and spell out their responsibilities in regulations.

The Patchogue, New York, ordinance empowers the village superintendent of public works to set up pertinent rules and regulations:

> Section 17—Refuse Disposal. . . . Refuse shall be disposed of at the Village incinerator only during the times designated by the Superintendent of Public Works and in accordance with the rules and regulations established by the Superintendent of Public Works.

Norwich, Connecticut, has a similar ordinance provision governing use of the city dump:

> Section 15. Public dumping grounds owned by the city shall be under the control and jurisdiction of the director of public works. He shall establish rules and regulations as to the time and conditions of use of such dumping grounds. It shall be unlawful for any person to

> use any such dumping ground except in compliance with such rules and regulations.

To use the city disposal grounds or incinerator in Rochester, New York, a general release must be signed by persons entering into contract disposal arrangements:

> Section 11.1. . . . All such persons, excepting those who are required to have filed with the comptroller a liability insurance policy as provided in 11.1-15, shall sign and file with the Department a general release in the form satisfactory to the corporation counsel, which shall absolve the city and its officers and employees from responsibility for any accident to said person or persons or their employees or for any damage to trucks or other property owned or operated by them, when such accident or such damage occurs in a city-operated incinerator or city-operated landfill, or on the grounds thereof. Such release shall be signed and filed as required upon each entry to the said premises.

Most cities find it desirable to restrict use of disposal facilities to designated times. The times that disposal sites can be used are set forth in the Manitowoc, Wisconsin, ordinance:

> 13.06 (3) Regulating the Public Dumps. Penalty. No person shall deposit, throw or place any rubbish, garbage, or other matter in or at the public dump or dumps maintained by the City of Manitowoc, between the hours of nine o'clock P.M. and six o'clock A.M. of the following day from the 1st of April to the 30th of September, and from eight o'clock P.M. to six o'clock A.M. of the following day from the 1st of October to the 31st of March of any year, or at any time on Sundays and legal holidays.

Sanitary landfill users in Knoxville, Tennessee, are specifically prohibited from burning refuse on the site:

> Section 13: Burning on city's dumping grounds. It shall be unlawful for any person to set fire to, or burn any papers, trash or garbage deposited within the city limits upon the dumping grounds used by the city for the depositing or dumping of such trash or garbage collected by the city trash carts, or trash wagons, without the permission of the superintendent of streets authorizing and directing such burning.

Salvage

Salvage or reclamation of re-usable components of refuse some times pays some of the costs of refuse disposal. If salvage by individuals or contractors is permitted at refuse disposal facilities, close regulation is essential.

The Albert Lea, Minnesota, ordinance specifies that all refuse delivered to the sanitary landfill is the property of the city and prohibits salvage unless authorized by the city manager or his representative:

> 6.2. All materials delivered and deposited for disposal on the Sanitary Landfill Area are the property of the City. No person shall separate, collect, carry off or dispose of such materials unless authorized to do so by the City Manager or his representative.

At Doylestown, Pennsylvania, scavenging at a landfill is prohibited:

> Article VII Section 2. It shall be unlawful for any person to enter

> the landfill area except when the attendant is present and at the hours prescribed by Borough Council. It shall be unlawful for any person to scavenge or remove any article from the landfill area.

In Philadelphia salvage of refuse on private disposal sites is permitted provided the operation is carried out as prescribed in the board of health's regulations:

> 8. Salvage Operations—(a) No person operating a private dump or landfill shall, or permit anyone else to, salvage or reclaim any food or food products, whether or not in a container, which may be delivered to the site for disposal. Such food or food products shall be promptly unloaded, spread and compacted to firmness, and covered to a depth of at least twenty-four (24) inches with other refuse material, or with cover material.
>
> (b) Salvaging or reclamation of materials (except food or food products) is permitted, provided all salvaged materials are removed to a location at such distance from the active surface as not to interfere with unloading, spreading, compacting or covering operations.

Control of Kinds of Refuse Disposed of at Municipal Facilities

Separation of Refuse

Whether all refuse is collected together or separated into components depends on the method of disposal.

Garden City, New York, requires that refuse delivered to the village incinerator and dump be separated into combustibles and noncombustibles and prohibits disposal of swill, slops, and offal:

> Section 11: Use of Disposal Facilities—The facilities of the municipal incinerator and dump will be available for the disposal of refuse herein designated . . . except swill, slops and offal. Such refuse shall be segregated as to combustible and non-combustible, shall be delivered during work hours only, and shall be unloaded or dumped at such locations and in such manner as may be directed. The Superintendent of Public Works shall have the right, however, to further regulate, restrict or prohibit the use of the municipal incinerator or dump as may be necessary in the public interest or due to operating conditions thereat or for repeated violation of regulations.

If sanitary landfills are used for disposal, usually all ordinary refuse is accepted without separation. Some items are considered extraordinary, however, and are not accepted for disposal.

The Alberta Lea, Minnesota, ordinance sets out the items not acceptable at the landfill:

> Section 3. Refuse Not Acceptable for Disposal.
>
> The City of Albert Lea will operate a Sanitary Landfill for the disposal of combined garbage and refuse. The following refuse shall be considered not acceptable for disposal in the City operated Sanitary Landfill:
>
> 3.1 Dangerous materials or substances such as poisons, acids, caustics, infected materials and explosives.
>
> 3.2 Any materials of any kind or nature, including ashes, that contain any hot live coals or fire.
>
> 3.3 Unusual quantities of materials resulting from the construction

> or wrecking of buildings and structures or that may result from manufacturing, industrial or agricultural processes.
>
> 3.4 All large and bulky materials such as auto car bodies that may require special preparation and processing for disposal.

Garbage, combustible refuse, and ashes are disposed of separately in the District of Columbia. Requirements for combustible commercial refuse received at the district's incinerators are given in police regulations, as follows:

> Sec. 26. . . . (d) The District of Columbia reserves the right to reject or further restrict deliveries of combustible commercial refuse at any time.
>
> Sec. 27. Combustible commercial refuse to be disposed of at the District of Columbia incinerators specified in Section 26 (a) of this Article shall conform with the following requirements:
>
> (a) Such refuse shall be readily combustible and shall not contain explosives, materials which may be toxic when burned, ashes, garbage, dirt, rock, or rubble.
>
> (b) No refuse subject to absorption of moisture, such as leaves, paper, and other materials capable of absorbing moisture, shall be delivered to the said incinerators in large quantities unless such refuse be dry or readily combustible. When the moisture content of such materials is high, the amounts received will be limited at the discretion of the Superintendent of Incineration or the Superintendent of Landfills.
>
> (c) No piece of combustible commercial refuse delivered to the above-specified incinerators for disposal shall be greater in size than 24 inches by 24 inches by 4 feet in length and larger articles, such as, for example, packing cases or furniture constructed of wood, cardboard, or other combustible material, shall be broken into pieces not larger in size than 24 inches by 24 inches by 4 feet.

Hazardous Refuse

Hazardous refuse as defined in the Hartford, Connecticut, ordinance includes:

> . . . cleaning fluids, crank case oils, cutting oils, paints, plastics, explosives, acids, caustics, poisons, drugs, radioactive materials, fine powdery earth used to filter cleaning fluid and refuse of similar nature.

Usually hazardous material is not accepted for the regular collection service and must be disposed of in a special manner as prescribed by regulations.

This is also stipulated in the Hartford ordinance, which places the responsibility for supervising disposal of radioactive materials and other hazardous substances upon the director of health:

> Sec. 18-10. Hazardous refuse.
>
> (a) No hazardous refuse will be collected by the department of public works but shall be transported by the owner, responsible person or agent to the municipal disposal area and disposed of as prescribed by the director of public works.
>
> (b) Radioactive materials, drugs, poisons and like substances shall be disposed of under the supervision of the director of health.

Dead Animals

The disposal of large dead animals is usually considered the responsibility of the owner. Large dead animals are usually disposed of at rendering plants if there is one within reasonable hauling distance. Some municipal incinerators can burn large animals such as horses and cows. Small animals may be incinerated or put in sanitary landfills.

In Detroit, Michigan, small dead animals are collected and disposed of by the department of public works upon proper notification, but large animals are handled separately:

> Sec. 306. All small dead animals, if kept separate from garbage and rubbish, will be collected without charge upon notice to the Department; provided that a charge will be made by the Department for all such animals collected from animal hospitals, kennels and the like. Owners of large dead animals shall be responsible for their removal and disposal.

Regulations of the Davidson County, Tennessee, health department specify method, time within which disposal must take place, and procedure for handling animals known to have or suspected of having a communicable disease:

> G. Disposal . . . 4. Dead animals shall be disposed of by burial or in an approved rendering or incineration plant. The owner of the animal, or if said owner cannot be found, then the person in charge of the property on which the dead animal is located is responsible for disposal within twenty-four hours by burying and covering with at least eighteen inches of earth or by arrangements for delivery to an approved disposal site or to a rendering or incineration plant as specified above. Dead animals will be accepted for disposal at County operated disposal sites provided they are delivered at a pre-arranged time at which they can be buried promptly as a part of the regular operation of the particular disposal site. In case an animal is known or suspected to have died of a communicable disease, the handling and disposal of the carcass must conform with laws and regulations of the State Department of Agriculture for the control of diseases of animals.

A schedule of fees for the removal and disposal of dead animals in included in the bylaws of Edmonton, Alberta, Canada:

> By-Law No. 283–23. Arrangements may be made with the Engineer's Department to remove the dead animals and the cost of such collection shall be charged as per the following schedule:

(a)	Pigs, Sheep and Calves– Pick-up, haul and cremate at Incinerator	$3.50 each
(b)	Cattle–Pick-up, haul and cremate at Incinerator	5.00 each
(c)	Horses–Pick-up, haul and cremate at Incinerator	6.50 each
(d)	Dogs–Pick-up, haul and cremate at Incinerator	.50 each
(e)	Cremating animals that are hauled to the incinerator by private parties, 25c per 100 lbs. or portion thereof.	

Control of Private Disposal Sites

In some cities all refuse disposed of within the corporate limits must be disposed of at municipally operated refuse disposal facilities. Most cities, however, permit private refuse disposal operations but control the activities at them.

In Louisville, Kentucky, a permit is required before noncombustible waste can be deposited:

> Section 19. Control of Dumps. It shall be unlawful for any person,

> firm or corporation to deposit or permit to be deposited any noncombustible waste on any land owned or controlled by such person, firm, or corporation without having first obtained a permit from the Director of Works to do so. Application for a permit to operate a private dump shall be made to the Director of Works, who shall issue such a permit if he is satisfied that the applicant is responsible and is willing to comply with the rules and regulations of the Director of Works concerning the operation of private dumps. Such permits shall be valid until revoked.

The Fresno, California, ordinance makes it unlawful for any person other than enfranchised garbage collectors to dispose of garbage:

> Section 9. It shall be unlawful for any person, within the City of Fresno, other than garbage collectors enfranchised by the City or duly authorized by the Fresno City Waste Disposal Department, to gather, collect, transport, burn, bury or dispose of any garbage or mixed garbage from any place where the same is placed by any occupant or other person described in Section 1 hereof, or to remove the contents of any garbage or mixed garbage receptacle.

Los Angeles issues permits for the operation of garbage disposal facilities, including incineration and reduction plants and ranches on which hogs are fed garbage. (The latter are controlled by state regulation in practically all states; particularly the cooking of the garbage.)

> Sec. 66.06. Garbage Disposal—Permits.
>
> (a) Any person disposing of garbage within the City by the methods of incineration or reduction, or disposing of garbage obtained by a duly authorized contractor from this City by such methods, shall make application agreeing to such rules and regulations as may be promulgated by the City for the construction and maintenance of any such incinerator or reduction plant in a sanitary manner and the disposal of any waste materials therefrom in a manner which shall not create a menace to human or animal health or a public nuisance, and shall thereafter receive a permit which shall be revocable at any time for cause.
>
> (b) Any person feeding garbage to hogs from any source other than the household or ranch on which the hogs are maintained must first make application agreeing to the rules and regulations embodying the principles set forth in Section 66.07 and Sections 34.06 to 34.08, inclusive, and shall thereafter receive a permit which is revocable at any time for cause.

The Davidson County, Tennessee, health department requires that the location and the equipment and methods used in feeding garbage to animals be subject to the approval of the director of health:

> 5. In cases where garbage is collected and used as food for hogs, cattle, or other animals within the county, such feeding must be done either at locations sufficiently removed from habitations, public places, or human activities to avoid the creation of nuisances or by means of such special equipment and methods as may be necessary for the prevention of nuisances. In all cases the location, equipment, and methods of feeding garbage to animals shall be subject to the approval of the Director of Health.

Hartford, Connecticut, requires that all dumping grounds be licensed and that owners keep them orderly:

> Sec. 18-15. Licenses for dumping grounds. The bureau of licenses and permits shall, with the approval of the director of health and at his discretion, issue and revoke licenses authorizing the dumping of ashes, rubbish and waste material, except garbage, and other offensive material on premises in the city, subject to the rules and regulations of the department of health as to the time and conditions of use, the materials that may be deposited in a particular location, and the placing and maintaining of signs indicating permitted uses.
>
> Sec. 18-16. Maintenance of dumps. It shall be the duty of the owner of any dumping ground to keep the same in an orderly condition, and when ordered by the director of health, to erect and maintain suitable fences to prevent the use of such place by unauthorized persons, or at times other than those specified in his permit.

The disposal method used by private collectors in the Borough of State College, Pennsylvania, must be approved by the board of health:

> Article No. 8–Disposal by the Collector. Section No. 1–The method used for the disposal of garbage shall be approved by the Boards of Health having jurisdiction. It shall be conducted and maintained so as not to create a public nuisance, permit fly breeding or be in any way a menace to the public health.

South Orange, New Jersey, requires as a license prerequisite proof that the scavenger has adequate disposal facilities and equipment and that the governing body of the area in which the site is located has given permission to use the site for refuse disposal:

> Section 4, 2. The applicant shall submit satisfactory evidence that:
>
> (a) He has a place for the disposal of ashes, garbage, rubbish and other collected material;
>
> (b) The said uses of such disposal site are assured for the period of the license;
>
> (c) The said place for disposal of ashes, garbage, rubbish and other collected material is located outside the limits of the Village of South Orange; that the use of such site for disposal is guaranteed for the period of the license; that the governing body of the municipality in which the said site for disposal is located has established a dump by ordinance and the applicant shall submit a duly authenticated copy of such ordinance; that the said governing body by resolution or other appropriate proceeding has selected and specified the site of said dump for the purpose of depositing ashes, garbage, rubbish and other materials, and the applicant shall submit a duly authenticated copy of such resolution or other proceeding; that a permit has been granted to the applicant for dumping purposes on said site by the Board of Health or other duly constituted authority of such municipality.
>
> 3. The applicant shall furnish an itemized list of all machinery and equipment owned by the applicant or available for use by the applicant in accordance with the provisions of this Ordinance. The applicant shall make the said equipment available for inspection by the Village Engineer, at reasonable times, during a period of ten (10) days prior to the hearing hereinafter provided for.

Sacramento County, California, requires that application for a permit to operate a refuse disposal area be approved by the board of health and the county planning commission and specifies "fill and cover method" and incineration:

> Section 19. The application for a permit to operate a refuse disposal area shall be made in writing to the Health Department on forms provided by the Health Department. If the Department finds from the facts that applicant is capable of complying with the provisions of this ordinance and the rules and regulations of the Health Department, said department shall issue a revocable permit for the conduct of the refuse disposal area. Such permit shall be issued for a period of two years and shall not be transferable. Renewal of permits shall be applied for and acted upon in the same manner as the original application. Before any permit shall be issued for a refuse disposal area, the proposed site shall be referred to the County Planning Commision to determine whether or not said disposal site is in a proper zone.
>
> Section 21. Except as herein provided, the refuse and rubbish disposal at all refuse disposal areas shall be by the fill and cover method, or by burning in properly designed and properly operated incinerators approved by the Health Department.

The Philadelphia department of public health has developed a comprehensive set of regulations governing private dumps and landfills:

> Section 9-604. Refuse Collection—(7) Private Dumps and Landfills.
>
> (a) No person shall operate or permit the operation of a private dump or landfill unless he has obtained a license from the Department of Licenses and Inspections.
>
> (b) No license to operate a private dump or landfill shall be issued unless:
>
> (.1) the applicant furnishes proof satisfactory to the Department of Licenses and Inspections of ownership of, or permission from the owner to use, the land on which the dump or landfill is located;
>
> (.2) the applicant furnishes a plan of the area of the private dump or landfill indicating the boundary lines, approximate elevations, established grade elevations, and approximate total cubic yards required to fill the area to established grades;
>
> (.3) the plan has been approved by the Department of Public Health;
>
> (.4) the applicant pays an annual license fee of $100, except that when an application is filed after the first six months of a license year the fee for that year shall be $50.
>
> (c) All licenses shall be conditioned upon compliance with S9-605 (7)(b) and with the regulations issued by the Board of Health and the Air Pollution Control Board with regard to the location and operation of private dumps.
>
> (d) No person shall deposit or permit the depositing of any refuse coming from a source outside the City on any private dump or landfill within the City.
>
> (e) When the Department of Public Health finds that a licensed private dump has been filled to the established grade levels, it shall so certify to the Department of Licenses and Inspections which shall cancel the license for the dump and refund to the licensee a pro rata amount of the license fee.
>
> (f) In addition to any fine or other sanction, the Department of

Licenses and Inspections may suspend or revoke the license of a private dump or landfill operator who violates any provision of this Section or any condition of a license.

1. Definitions—(a) Private dump or landfill. Real property in or upon which refuse is deposited, other than when operated by the City.

2. Scope of Regulations—These regulations shall apply to all private dumps or landfills, except the receipt or storage of cover material and the disposal by a householder of his own household refuse on the property where he lives.

3. Supervision—A person in responsible charge of operations shall be on duty at private dumps or landfills continuously during the hours of active operation.

4. Trespassing—Effective measures shall be taken to prevent trespassing or dumping at private dumps or landfills by unauthorized persons, and to prevent trespassing and dumping when unattended.

5. Receipt of Dangerous Materials—Where the operator of a private dump or landfill has knowledge of, or reason to know of, the inclusion of dangerous materials in refuse delivered to the private dump or landfill, he shall receive, handle, and dispose of such materials in accordance with procedures established by or in a manner approved by the Department of Public Health.

6. Operation—(a) All private dumps and landfills within the City of Philadelphia shall be operated as sanitary landfills. . . .

7. Surface Elevations . . . .

8. Salvage Operations . . . .

9. Access Roads . . . .

10. Water Supply . . . .

11. Drainage and Water Pollution . . . .

12. Rodent and Arthropod Control . . . .

13. Fencing . . . .

14. Disasters or Emergencies—When, in the opinion of the Health Commissioner, a period of disaster or emergency exists involving Public Health, he may waive any of the provisions of these regulations for a period not to exceed thirty (30) days.

15. Approval of Application for License for Private Dumps or Landfills—Plans for private dumps or landfills submitted to the Department of Public Health for approval shall be accompanied by such information as the Department of Public Health may request to show how the proposed operation of the private dump or landfill will comply with these regulations and with Sections 9-604(7) and 6-214 (1)(g) of The Philadelphia Code.

16. Inspection—Authorized representatives of the Department of Public Health shall be permitted to enter private dumps or landfills at any time for the purpose of determining compliance with these regulations or with Section 9-604(7) and Section 6-214(1)(g) of The Philadelphia Code, and the owner, operator, or person in charge shall give such representatives free and unhindered access for inspection purposes.

ON-SITE DISPOSAL

On-site, or on-premises, disposal is said to be the most widely used means of refuse disposal in the United States. Since on-site disposal is usually interpreted to mean the use of garbage grinders and burning (not necessarily incineration), the term disposal is used loosely. Actually, final disposal of much of the refuse is done off the premises. It is important, therefore, to regulate on-site disposal to prevent nuisances and health hazards.

The City of Detroit has promoted the use of food waste grinders; and has set up standards and controls governing their installation and the use of domestic burning equipment:

> 1.11a—Domestic refuse burning equipment: any refuse-burning equipment or incinerator having a firebox or charging compartment of not more than 5 cubic feet in capacity.
>
> . . . .
>
> 2.6a—It shall be unlawful for any person, firm, corporation or their agents to import, sell, offer for sale, expose for sale, exchange, deliver or install for use in the City of Detroit:
>
> (1) Any make, model, or type of domestic refuse burning equipment which has not been approved by the bureau.
>
> (2) Any make, model, or type of approved domestic refuse burning equipment for the burning of any type of refuse other than the types for which the refuse burning equipment has been approved by the bureau.
>
> (3) Provided that the importation, delivery or transportation of such domestic refuse burning equipment by railroad companies and other common carriers in the course of their common carrier business, shall not be deemed to be a violation of the provisions of this section.
>
> 2.6b—Prior to approval, each make, model or type of domestic refuse burning equipment shall be submitted to the bureau and be subjected to such tests as may be deemed necessary to establish the performance efficiency, durability, minimum installation requirements, air pollution potential and fire hazard potential under ordinary operation. For fire hazard potential and efficiency determination, nationally recognized standards such as those of the American Gas Association and the Underwriters Laboratories may be employed.
>
> (1) The bureau shall list each make, model or type of domestic refuse burning equipment which it has approved, and shall designate the approval as being limited to one of the following four categories:
>
> Type A. Outdoor burning equipment for ordinary paper or similar material only.
>
> Type B. Indoor burning equipment for ordinary paper or similar material only.
>
> Type C. Rubbish incinerator for burning ordinary paper, rags, floor sweepings or similar material only.
>
> Type D. Domestic incinerator for burning rubbish and garbage.
>
> (2) Any approved domestic refuse burning equipment, except Type A, that is imported, sold, offered for sale, exposed for sale, exchanged, delivered or installed for use in the City of Detroit shall bear a plate or tag in accordance with the regulations of the department which identifies the equipment and the category for which it is approved.
>
> (3) Any person, firm, or corporation whose domestic refuse burning equipment is submitted to tests by the bureau must pay all ex-

> penses necessary to the attendant tests, and the bureau shall furnish the submittor a copy of the results of such tests. . . .
>
> . . . .
>
> 2.11—Plans and specifications so filed with the Department shall show the type of installation, the amount of work and the amount of heating to be done by such fuel or refuse-burning equipment and all appurtenances thereto, including all provisions made for the purpose of securing complete combustion of the fuel or refuse to be used and the manner in which it is to be burned for the purpose of preventing smoke and other air pollution as provided by this Ordinance.
>
> (a) Such plans and specifications shall also contain a statement of the rate of burning and kind of fuel or refuse proposed to be used and the manner in which it is to be burned.
>
> (b) Such plans shall further show the dimensions of the room in which such fuel or refuse-burning equipment is to be located, the location and dimensions of all stacks used in connection with or as a part of said fuel or refuse-burning equipment.
>
> (c) The Bureau may require such additional data as is deemed necessary for the purpose of issuing a permit for the operation of such fuel or refuse burning devices. . . .

Although few if any cities require food waste grinders in all dwellings, a number of cities require them in new construction.

The Detroit ordinance includes such a requirement:

> Section 3. Structures erected in the City after January 1, 1956, designed, arranged or intended to be used for purposes which cause, result in, produce or develop food wastes, and all structures converted or altered for such purposes, shall provide approved food waste disposal equipment for such purposes within the premises thereof. It shall be unlawful for any person to use, permit or cause to be used any such structure that does not conform to the provisions of this section.
>
> Section 4. The Department of Buildings and Safety Engineering, through its officers, inspectors, or employees, shall enforce the provisions of this Ordinance.
>
> Section 4.1. The installation, operation, and maintenance of any equipment or method to be used for on-the-site disposal of food wastes, shall comply with the applicable provisions and regulations of the building, housing, plumbing, electrical, smoke abatement, air pollution, safety engineering, health, sanitation, and fire ordinances of the City.
>
> Section 5. The Commissioner shall have on file in the Department, a list of approved food waste disposal equipment.

A Lombard, Illinois, ordinance specifies that dead leaves and similar wastes may be burned on the premises under certain conditions and permits the installation of incinerators and grinders under certain conditions:

> Section 9. Disposal Other than Collection:
>
> (a) Dead leaves and other wastes from plants may be burned upon a lot or plot of ground upon which such waste has accumulated, if proper precautions are taken to prevent the spread of fire, and provided further that no nuisance is created by such fire.
>
> (b) Garbage and other combustible wastes may be disposed of

> within the building where it accumulates or within a closed building accessory thereto situated on the same premises by complete incineration of such garbage or wastes in such a manner as to create no noxious odors, fire hazard, smoke or other nuisance, by grinding or shredding it finely and disposing of it through pipes leading to a public sanitary sewer, provided that all garbage or combustible matter so disposed of in such pipes shall have been ground or shredded to such a degree that all particles are carried freely under the flow conditions normally prevailing in the sewers into which such is deposited, with no particle greater than one-half inch in any dimension and further provided that all incinerators or grinders used for such disposal of wastes must be approved by the Health Officer and the Village Manager or their respective representatives.

The Davidson County, Tennessee, health department requires that if on-site disposal is used, refuse must be stored in the same way it would be if the refuse were stored for collection:

> 6. Persons who propose to dispose of refuse on their individual premises must observe the same conditions of storage as would be required if the refuse were stored for collection, as specified in D above. Garbage may be disposed of by adequate burial and covering with earth but garbage and refuse containing garbage shall not be burned except in a high temperature furnace. Refuse that does not contain garbage, dead animals, night soil, or manure may be disposed of in any manner that will not cause nuisance from appearance or odor or provide harborage for rats or a breeding place for flies and other insects. When it appears that the methods employed for disposal of refuse on individual premises is causing or may cause a nuisance, collection, removal, and disposal in accordance with the foregoing regulations may be required by the Director of Health.

Air Pollution Controls

During the 1950's the serious air pollution problems in many urban areas received increased attention. Among the first air pollution nuisances studied were smoke and odors from improperly disposed of wastes. Back yard burning of combustible refuse and open burning of refuse on dumps were found to be significant contributors to atmospheric pollution in such metropolitan areas as Los Angeles and Philadelphia. Incinerators in apartment houses and similar places were also often found to be heavy contributors.

As a result, many municipalities in recent years have passed ordinances to control disposal practices. Probably the first and most popular step was to limit or outlaw open burning.

The Newark, New Jersey, health and sanitation ordinance, adopted in 1951, requires that a permit be obtained for burning, restricts the hours of burning, and limits the location of dumps in which burning is permitted:

> Sec. 15.654. Burning certain waste matter—Permit required. It shall be unlawful to set fire to, or burn, any of the items specified in section 15.651 of this Revision, on any dump licensed as herein provided, without first obtaining a permit from the inspector of combustibles and fire risks of the city. (8-22-51, S3.)
>
> Sec. 15.655. Same—Hours permitted; water facilities. The controlled burning of combustible rubbish, paper, cardboard, wood and trade wastes will be permitted only during the daylight hours from 9:00 A.M.

> to 5:00 P.M. of each day, exclusive of Sundays, or holidays. Adequate water facilities must be available for the control of these fires and to deal with all other fires such as are caused by spontaneous combustion. (8-21-51, S4.)
>
> Sec. 15.656. Location in accordance with zoning regulations. Any and all dumps licensed under the provisions of this division shall be located only in such place or places as is permitted by the zoning ordinances of the city. (8-22-51, S6.)

Salt Lake City sanitary regulations prohibit burning of refuse in furnaces and stoves, as well as outdoor burning:

> Sec. 18-3-16. Burning of refuse. It shall be unlawful for any person to burn garbage, market waste, manure, or other offensive refuse in the open air, or in any furnace or stove within the city limits; provided however, that trade waste and other similar refuse may be burned at the city incinerating plant, or other places designated by the board of health.

The Rapid City, South Dakota, ordinance prohibits outside burning of garbage but permits burning of refuse such as newspapers:

> 6.0606. Burning Garbage. No garbage or other matter from which offensive or noisome odors emanate during combustion shall be burned outside of any building.

Burning on the city dump by the public is prohibited in Traverse City, Michigan:

> 502.5. No person shall set fire to or burn any matter of any kind on the refuse ground of the City in Garfield Township, Grand Traverse County, except the attendant at the refuse ground.

In Omaha, Nebraska, regular burning of refuse is prohibited but certain types of burning is permissible with the special permission of the fire department:

> 18-6.4 (a) It shall be unlawful to conduct open or unconfined burning within the limits of the City of Omaha either on public or private property except at the discretion of the Chief of the Fire Department and then only upon the receipt of special permission of said Fire Chief or his authorized agents and specifying the time and location at which said authorized burning will take place. Such burning when authorized shall not be carried on closer than 25 feet from any permanent structure unless said permission specifically allows it, nor shall any burning permitted under this section be carried on without one or more persons in direct attendance and as may be specified by the Fire Chief or his agents.
>
> (b) All regular burning of waste material and combustibles of every type, including wood, paper, cardboard, rakings, leaves, grass, weeds, litter, sweepings, and all waste within the confines of the City of Omaha must be conducted within a properly designed and constructed incinerator or closure which is up to the minimum safety standard specified in this ordinance and conforming further with ordinances of the City with respect to the structural standards and smoke emission.
>
> (c) It shall be unlawful to conduct open burning of waste materials, wood, paper, cardboard, rakings, leaves, grass, weeds, litter, sweepings, and all waste in public paved streets, alleys, or public areas.

The burning of garbage is prohibited in Albuquerque, New Mexico, but dry combustible refuse may be burned between sunup and sundown under specified conditions.

> Section 1—No garbage shall be burned in the open air within the City of Albuquerque provided however that dry combustible waste paper, trash, weeds and leaves may be burned between the time of sunrise and sundown and any day when burned no closer than twenty five (25) feet from any dwelling and guarded by a person over the age of fourteen years, and such fire shall be extinguished at sundown in such a manner as to prevent smoke and smudging.

Standards of incineration of refuse are prescribed by air pollution control authorities in such cities as New York, Philadelphia, Detroit, Chicago, and Los Angeles. Although regulations vary according to local needs, the Philadelphia controls are considered more or less typical of requirements in large cities:

> Section 4A—Limits and Measurements
>
> (a) No person may cause, suffer or allow to be discharged into the open air dust, fume, gas, mist, odor, smoke, vapor, or any combination thereof, from any single point, vent, stack or source which constitutes air pollution or an air pollution nuisance or which is of a shade in excess of No. 2 on the Ringelmann chart or its equivalent for a period of more than two (2) minutes in any fifteen (15) minutes; or for more than three such two (2) minute periods in any one day;
>
> (a-1) except when building a new fire, when adjusting new equipment, when a breakdown of equipment occurs, or in the operation of mobile equipment, and prompt notice of such exceptions is given to the Department of Public Health, Air Pollution Control Division, one initial startup allowance of ten (10) minutes in sixty (60) minutes shall be permitted when dust, fume, gas, mist, odor, smoke, vapor or any combination thereof, not to exceed No. 3 on the Ringelmann chart or its equivalent may be emitted:
>
> (a-2) except that when soot blowing, with a resultant emission of dust, fume, gas, mist, odor, smoke, vapor, or any combination thereof, in a shade in excess of No. 2 on the Ringelmann chart or its equivalent may be permitted for not more than a reasonable scheduled time agreed to by the Air Pollution Control Division prior to any such emissions:
>
> (a-3) In the case of an emission having a color other than black, an equivalent density as shown by any equivalent density scale approved by the Air Pollution Control Board may be used.
>
> (a-4) All references to the Ringelmann chart mean the "Standards and Instructions" published by the United States Bureau of Mines (Circular 6888, dated 1936, revised April 1941) to determine the density of smoke.
>
> (b) Dust, fume or smoke discharged into the open air, or passing any convenient measuring point, from any fuel fired combustion process, shall not: (1) exceed 0.85 pounds per 1,000 pounds of gases adjusted to 12 per cent CO_2 (carbon dioxide) content; or (2) create air pollution or an air pollution nuisance at any time or place.
>
> (c) When applicable, the Air Pollution Control Division, in attempting to evaluate the environmental extent of and effects of toxic contaminants in the atmosphere, may be guided by the limits set forth

in "Table of Threshold Values" adopted by the American Conference of Governmental Industrial Hygienists in April 1952, or by any of the limits relating to this subject published by the American Standards Association, the American Petroleum Institute, the Manufacturing Chemists Association, the National Safety Council, or any other recognized authority that the Air Pollution Control Board deems advisable. It is recognized that in some cases such limits are partially based on animal experimentation as related to a normal person being exposed for a forty-hour week. Adjustment for other exposures and conditions and for a reasonable range of deviation from normal will be made.

(d) The measurement or evaluation of the amounts of matter, or concentration of pollutants, may be by the observation of trained observers or by such other methods and procedures as may be approved by the Air Pollution Control Board either in these Regulations or at meetings of the Board.

(e) After due consideration of specific technical data assembled by the Board or submitted by any person which shows that limits in the Regulations in a particular area can be modified without prejudice to the public interest or should be strengthened in the public interest, the Air Pollution Control Board may approve special changes of limits for specific areas for a reasonable trial period of not more than six (6) months. After such trial period, the Air Pollution Control Board may set for each such area suitable limits based on such experience and their best judgment in the light of the provisions and purposes of the Ordinance.

Financing

Charges for disposing of refuse at municipally operated or regulated landfills or incineration plants are levied in many cities, but practices vary considerably. Some cities (Washington, D.C., for example) levy no charge for the disposal of ordinary residential and commercial refuse from within the city; disposal costs are paid out of general tax funds. On the other hand, many cities charge householders for both collection and disposal.

If refuse is weighed, rates are almost always based on weight; if not, the basis is load, kind of vehicle, or volume.

Rates for a number of cities are:

Tacoma, Washington

Code Section 5.20.180—Use of Dumps—No person shall use or be permitted to use any dump or dumps, sanitary fill or fills or other place of disposal established and used by the Public Works Department, Utility Services Division, except with the approval of the Public Works Department and in accordance with all of its rules and regulations and the following schedule of rates:

Up to 7,000 lbs. gross vehicle weight	$ .50
8,000-19,999 lbs. gross vehicle weight	1.00
Over 20,000 lbs. gross vehicle weight	1.25

For refuse brought in a private car,
with or without a trailer, or pickup
truck from the driver's residence,
no charge.

Provided, however, every person with refuse requiring special handling shall pay such additional charge as will fairly compensate the Public Works Department for the expense of properly disposing of such refuse.

The foregoing rates shall be inapplicable to persons engaged in the business of collecting and hauling garbage and refuse in areas outside of the City of Tacoma; as to such persons, the charge shall be $0.19 per cubic yard of garbage and refuse.

Sandusky, Ohio

Section 2. That the following schedule of rates shall be charged for the disposal of refuse, rubbish and/or garbage at the Sanitary Landfill operated by the City of Sandusky in Perkins Township, Erie County, Ohio:

(1) For all refuse, rubbish and/or garbage hauled in an automobile .... $ .25

(2) For all refuse, rubbish and/or garbage, except that hauled in an automobile: 12½c for each 100 pounds or part thereof, except there shall be a minimum charge of 25c.

(3) For all refuse, rubbish and/or garbage, except that hauled in an automobile, a non-resident of the City of Sandusky who is permitted to use the landfill shall be charged an additional twenty per cent (20%).

Wichita, Kansas

Sec. 13-29. Authority of the City—Dumping Fees. The Sanitation Director shall prepare a schedule of fees for the disposal of refuse, which shall be effective upon approval by the Board of City Commissioners. When such fees are approved, they shall be payable to the City for disposal services performed by the Sanitation Division; subject, however, to change by the Sanitation Director upon the approval of the Board of City Commissioners.

Refuse Disposal Service Charge Schedule

Type of Vehicle	Rate per Load
Automobiles	No charge
Commercial Station Wagons	$0.25
Two-Wheel Trailers	0.25
Trucks Rated 8,000 pounds or less G. V. W.	0.25
Four-Wheel Trailers	0.35
Trucks Rated 12,000 or 16,000 pounds G. V. W.	0.35
Trucks Rated 20,000 pounds or over G. V. W.	0.50
Semi-Trailers	0.50

Morgantown, West Virginia

Article III—Section 1—(f) Minimum Charges for Refuse Delivered to the Location of Disposal without Expense to the City:

Horses, cattle or other large animals	$25.00
Cats or dogs	$ 1.25

Raw garbage (as defined), at the rate of $4.50 per ton or any fraction thereof, with a minimum charge of $1.25.

> Trash (as defined), at the rate of $4.50 per ton or any fraction thereof with a minimum charge of $1.00.
>
> Other materials at rates set by Superintendent after inspection and examination of load. All such charges shall be collected upon delivery to the disposal location.

Pendleton, Oregon

> Section 17. . . . Any collectors using the city refuse disposal site to deposit garbage and rubbish collected outside the city shall be charged a fee of 25% of the gross receipts derived from fees charged their customers outside the city limits of the City of Pendleton for the collection and removal of garbage and rubbish. Such garbage collector shall keep proper books and records concerning his garbage collection and removal operations, which books and records shall always be open to the inspection of the City of Pendleton.
>
> Section 19. There is hereby created a "Sanitation Department Regulatory Board" which board shall be composed of one member of the City Council and two residents of the City of Pendleton appointed annually by the Council. The Regulatory Board will act as arbitrators in all matters referred to them concerning garbage rates, service, and policy, but decisions of the board shall be reported to the City Council which will approve or disapprove of the same. The determination of the Council shall be final.

In Richmond, California, a contractor is authorized to operate the disposal site provided by the city and to charge within specified limits:

> Section 12.1: Said contractor may charge all persons, firms or corporations using said premises for the purposes of depositing garbage and/or rubbish thereon at rates not exceeding those hereafter specified as follows:
>
> For use of said premises by commercial houses and industries having their places of business or plants within said city: Automobiles, trailers and pick-ups not exceeding ½ ton each, 50c; trucks not exceeding 1½ tons each, 75c; clean fill, no charge; trucks hauling rubbish and garbage mixed with dirt, any size truck each, $1.00; semi-trailer, any size each, $2.00; when material to be disposed of is either highly combustible or inflammable or of such nature that special supervision is required to be supplied by the contractor to dispose of it properly, any size load in any vehicle each, $4.00.
>
> For use of said premises by persons, commercial houses or industries living or having their places of business or plants without said city: Household garbage and rubbish per can of garbage or load of rubbish, 25c; automobiles; trailers and pick-ups not exceeding ½ ton each, 75c; trucks not exceeding 1 ton each, 75c; clean fill, no charge; trucks between 2 and 3 tons each, $1.75; trucks 3 tons and over each, $2.25; semi-trailer, any size each, $3.00; when material to be disposed of is either highly combustible or inflammable or of such nature that special supervision is required to be supplied by the contractor to dispose of it properly, any size load in any vehicle each, $5.00.

The Doylestown, Pennsylvania, ordinance sets fees for use of the borough's landfill and provides for monthly billing of licensed collectors:

> Article IX—Fees for use of landfill—Section 1. The attendant on duty at the Borough landfill shall keep a daily record of all refuse

> deposited by licensed collectors or others from whom fees are due. At the end of each day he shall transmit said record to the Secretary who shall, at least monthly, bill the collector or other persons from whom fees are due as hereinafter set forth.
>
> Section 2. Each licensed collector, each contractor transporting building rubble and each owner of commercial property transporting refuse therefrom shall pay to the Borough a fee for the privilege of depositing refuse in the landfill, as follows:
>
> (a) Each load or part thereof from a "Load Packer" or similar vehicle $1.00
>
> (b) Each load or part thereof from all other vehicles except "Load Packers" or similar vehicles $0.50

Cincinnati charges for incinerating refuse from beyond the limits of the city:

> Sec. 707-31a. Charge for Incinerating Combustible Waste and Garbage. A service charge of five dollars ($5.00) per ton shall be made for the incineration of combustible waste and garbage delivered at public incinerators and originating from sources beyond the limits of the city.

Rates for disposal of refuse delivered to the municipal incinerator at Edmonton, Alberta, Canada, are specified in the by-laws:

> By-Law No. 1283, 23. . . . Other waste delivered to the Incinerator will be burned at the following rates:
>
> Loose refuse such as shavings and papers, 15c per 100 lbs.
>
> Other waste, excepting animals (as above), 20c per 100 lbs.

Private collectors of refuse are licensed by the Department of Sanitation in New York City. Each permit holder has the privilege of disposing of refuse at the sanitation department's disposal facilities upon payment of the charge fixed by the Board of Estimate and in compliance with rules and regulations. A ticket system of payment, as prescribed in the rules and regulations of the department, is used:

> Section 4—Payments:
>
> a—Payment shall be made in advance by the purchase of books of tickets from the Chief Clerk of the Department of Sanitation at his office, Room 725, 125 Worth Street, Manhattan, New York 13, N. Y.
>
> b—The office of the Chief Clerk will be open for the sale of books of tickets only at these times: Mondays to Fridays, inclusive, 9 A.M. to 4 P.M.
>
> c—Each prospective purchaser shall identify by the D.S. waste conveyance truck permit number, the vehicle for which it is desired to purchase tickets.
>
> d—Only cash, U. S. postal money order or note, or certified check drawn on a State or National Bank located in the City of New York, or officer's check of such a bank will be received and accepted in payment for tickets. All such checks shall be drawn to the order of "Department of Sanitation," as payee.
>
> e—Tickets will be sold in books of twenty-five (25) tickets, each separate ticket being in payment for one load at the cubic capacity calculated and determined by the Commissioner of Sanitation for the body of the particular vehicle for which the ticket is sold and purchased.

f–Tickets will be sold only for a vehicle for which a D.S. waste conveyance truck permit has been issued under Sections 755(2)-6.1 and 755(2)-6.2, Administrative Code.

g—One ticket shall be delivered by the method prescribed in the next paragraph to the Commissioner's representative at the Department location where material is offered for each load or partial load, in advance of dumping and as a condition to receipt and acceptance thereof.

h—When offering a load for disposal, the permit holder or his employee shall deliver to the Commissioner's representative the embossed metal plate issued by the Department with the permit listing permit number, cubic yard capacity of vehicle body, and name and address of permittee, and the current ticket book in use for the vehicle. Tickets shall not be detached and offered separately. The Commissioner's representative will detach and retain the next unused ticket from the book in numerical order and, after complying with Department instructions as to recording, return the embossed plate and book of remaining tickets to permittee or his employee, instructing him where and how to dump the load. When the last ticket in a book is used for a load, the Commissioner's representative will retain the book cover and forward it in accordance with Department instructions.

i—The Commissioner of Sanitation is without power to make to, or secure for purchasers, refunds for unused tickets. Unused tickets should be delivered (or sent by registered mail) to the Comptroller's Bureau of Law and Adjustment, Municipal Building, Manhattan, New York 7, N. Y., together with a written demand for refund, giving purchaser's name and address, permit plate number, vehicle registered capacity, and book and ticket numbers surrendered.

j—Requirements for prepayment shall not apply to purchase contracts or purchase orders of U. S. Government agencies.

Provisions for calculating the volume of refuse delivered to New York disposal facilities are included in Section 3. These are applicable if weighing facilities are not available.

e–To calculate the load charge for the volume of material that may be carried in the body of a particular vehicle, the Commissioner's representative will measure the body of the vehicle.

f—In determining body capacities for purposes of payment, calculations will be made to the hundredth of a cubic yard. When the calculated capacity contains a fraction not exceeding fifty one-hundredths (50/100's) of a cubic yard, capacity will be fixed at the whole number of cubic yards less the fraction. When the fraction exceeds fifty one-hundredths of a cubic yard, capacity will be fixed at the next higher whole number of cubic yards.

g—The manufacturer's rated cubic body capacity for a totally enclosed body may be accepted, or such body may be measured and capacity calculated.

h—Some dangerous materials may be accepted but only after special arrangements have been made through the Bureau of Waste Disposal at the Department's Main Office, 125 Worth Street, Manhattan, New York 13, N. Y.

Penalties for Violations; Severability

Provisions for penalties for violations of all or part of refuse collection and disposal ordinances and a severability clause are common.

The provisions in the Temple, Texas, ordinance are typical:

> Penalty:
>
> Any person or persons, firm or corporation who violates any of the provisions of this ordinance shall be deemed guilty of a misdemeanor and upon conviction shall be fined not less than Five Dollars ($5.00) nor more than Two Hundred Dollars ($200.00) for each offense, and each violation hereof shall be deemed a separate offense and each day's continuance or failure to comply herewith shall constitute a separate and distinct offense for each of said days and shall be punishable as such.
>
> Severability:
>
> Should any Section, Paragraph, Sentence, Clause or Phrase of this ordinance be declared unconstitutional or invalid for any reason, the remainder of said ordinance shall not be affected thereby.

Appendix C

ORDINANCE, SPECIFICATIONS, PROPOSAL, AND CONTRACT FOR REFUSE COLLECTION AND DISPOSAL, SEATTLE, WASHINGTON, 1958 THROUGH 1962

City of Seattle
Department of Public Works

Ordinance, Proposal, Specifications and Contract

for

GARBAGE, RUBBISH AND CERTAIN TRADE WASTE COLLECTION
OPERATION AND MAINTENANCE OF THE VARIOUS DISPOSAL SITES
AND THE PROVIDING AND PLACING OF EARTH COVER AT THE
VARIOUS DISPOSAL SITES IN THE CITY OF SEATTLE

Prepared by
Roy W. Morse, City Engineer

Bid Opening
2:00 o'clock p.m., September 11, 1957
Pacific Standard Time
Room 512, County-City Building
Seattle 4, Washington

ORDINANCE NO. 86373

AN ORDINANCE relating to and regulating the keeping, collection and disposal of garbage, rubbish and trade waste; authorizing certain contracts in connection therewith; defining offenses and prescribing penalties and repealing Ordinance 80726.

BE IT ORDAINED BY THE CITY OF SEATTLE AS FOLLOWS:

Section 1. It is unlawful to deposit, throw, or place any garbage, rubbish, refuse, or other waste as herein defined on any property, public or private, or in any lane, alley, street or other public place, except in garbage cans or in ordinance units, as hereinafter described, placed on private property, or on the street or alley when, in the judgment of the City Engineer, necessary or required. Such cans shall be kept tightly covered and the covers shall not be removed, except when necessary.

Section 2. Garbage, rubbish, and certain trade waste, as herein defined, accumulated in the City of Seattle, shall be collected by the City's "contractor" from all premises, public and private, including all docks, ferries and passenger ships lying at dock and all public park concessions, except from military establishments, military housing projects or from the University of Washington Campus.

Section 3. Until the termination of the present "swill contract," "swill" shall be segregated as contemplated by Ordinance Nos. 60085 and 80451;

thereafter such "swill" may not be segregated and will be collected as "garbage."

Section 4. It shall be unlawful for anyone except the University of Washington, the military establishments or their agents or contractors, and the City's "contractor," to haul garbage or putrescible trade waste through the streets of the City of Seattle, except when permitted by the City Engineer and the Director of Public Health.

Section 5. The meaning of terms and words as used herein shall be as follows:

A. "GARBAGE" means every accumulation of animal, fruit, food, and vegetable waste from the preparation, processing, cooking, consumption, storage or handling of animals, meats, fish, fowl, fruits and vegetables, other than trade waste as defined in Section 5, C. Garbage shall also mean small dead animals weighing not over 15 pounds and waste from central kitchens for chain restaurants.

B. "RUBBISH" means discarded nonputrescible waste matter, including, but not limited to, ashes, yard trimmings, household furnishings, paper, boxes, bottles, other containers or rags, other than trade waste. The word rubbish shall include earth, sand, gravel, rocks, concrete, building material, automobile bodies or large machine parts.

C. "TRADE WASTE" means any waste materials from factories, processing plants, manufacturing plants, slaughter houses, commissaries, commission houses, wholesale houses, jobbing and wholesale produce establishments.

D. "GARBAGE CAN" means a round, watertight, sheet metal raised bottom container, not exceeding thirty gallons in capacity, weighing without cover not over twenty-six pounds when empty, fitted with two sturdy handles, one on each side, and a tight cover equipped with a handle. Cans with bails must have the bails removed prior to collection. The term shall also apply to other containers of similar size and weight when approved by the City Engineer.

E. "ORDINANCE UNIT" means one box or carton, either empty or filled with rubbish as herein defined, or one small shrub or small tree. The term shall also apply to rubbish in general when such material is disassembled, broken, or cut up and placed in securely tied bundles. All ordinance units shall be securely tied by the occupant and shall be of such size that the longest dimension thereof shall not exceed three feet and the volume shall not exceed twelve cubic feet; and provided further, that the total weight of any ordinance unit shall not exceed one hundred pounds. The term shall also apply to hot water tanks up to and including 30-gallon capacity.

F. "GARBAGE DISPOSAL SITE" and "DISPOSAL SITE" mean the areas owned, leased or controlled by the City for the disposal of garbage, rubbish, or trade waste.

G. "CITY ENGINEER" means the City Engineer of the City of Seattle, and his authorized employees.

H. "CITY" means the City of Seattle, and "THE BOARD OF PUBLIC WORKS" means the Board of Public Works of said city.

I. "CONTRACTOR" means the one contracting with the City to collect and dispose of garbage, rubbish and certain trade waste as herein described, or the authorized representative of such contractor.

J. "RESIDENCE" means a building or portion thereof containing not more than four dwelling units.

K. "APARTMENT HOUSE" means a building or portion thereof containing five or more dwelling units.

L. "ALLEY" means public or private way giving access to the rear of lots or buildings.

M. "STREET" means a public or private way, other than "alleys," used for public travel.

Section 6. All premises, public and private, including all docks, ferries and passenger ships lying at dock, and all public park concessions, must have and use a sufficient number of garbage cans to hold all their garbage and ashes. In lieu of the use of such garbage cans, anyone may, with the consent of the City Engineer and the contractor, provide other containers. Additional amounts of rubbish, bundled in ordinance units as herein defined may be set out for collection. On and after January 1, 1958, up to two ordinance units per collection shall be collected by the contractor for each garbage can used from all residences. One ordinance unit per collection shall be collected by the contractor for each garbage can used from all other premises, except from factories, processing plants, manufacturing plants, slaughter houses, commissaries, commission houses, wholesale houses, jobbing and wholesale produce establishments. The removal of additional ordinance units shall be arranged for by the occupant, and if so requested, the contractor shall collect such additional ordinance units during regular collection trips at the price approved or fixed by the Washington State Public Service Commission, to be paid to the contractor by such occupant.

Section 7. No garbage shall be placed in boxes or ordinance units.

Section 8. No hot ashes shall be placed in any garbage can.

Section 9. All garbage cans shall be kept in good condition for garbage and handling. No garbage can which leaks or has jagged edges or holes shall be used. The City Engineer at the request of the contractor, in writing, shall determine whether or not the condition of any can is satisfactory for use.

Section 10. No garbage can, when filled, shall weigh more than one hundred pounds, and it shall be so packed that the contents thereof will dump out readily when the can is inverted.

Section 11. All garbage cans and ordinance units shall be placed by the occupant in convenient, accessible locations upon the ground level or ground floor, as near as practicable at the approximate rear of the building or near the alley or such other locations as may be approved by the City Engineer or, where no such area is available, as determined by the City Engineer, garbage cans or ordinance units may be placed on the sidewalk or in the alley for collection, but shall not be so placed until a reasonable time prior to collection and shall be removed at a reasonable time thereafter. Housing projects, trailer parks, bungalow courts, garden courts, apartment houses and motels shall use central stations when directed so to do by the City Engineer.

Section 12. All walks, paths, and driveways to the place of loading shall have an overhead clearance of not less than eight feet.

Section 13. Small amounts of tar paper (in small pieces), sawdust, small blocks of wood, broken plaster and other waste building materials resulting from minor home maintenance projects in residences or apartment houses will be collected at each collection when the aggregate weight of such materials does not exceed ten pounds per garbage can.

Section 14. It shall be unlawful, except as authorized by the occupant of the premises or the City, to deposit any material in any garbage can, or to remove the cover therefrom or to remove or disturb any of the contents thereof except for collection.

Section 15. Collection and disposal of anything not defined herein as garbage or rubbish, shall be excluded from collection by the contractor; provided, that all establishments producing trade waste as herein defined, are entitled to collection of one garbage can of trade waste at each scheduled collection.

Section 16. The Board of Public Works is hereby authorized and directed to call for alternate bids for the collection of garbage, rubbish and certain trade waste; for the providing of earth for cover at the various disposal sites; and for the collection and disposal of garbage, rubbish and certain trade waste, including the collection, disposal and maintenance of the various disposal sites plus the furnishing and placing of the earth for cover; all in accordance with the specifications and forms of contract attached hereto and marked Exhibits "A," "B" and "C." The Board of Public Works is authorized to award a contract to the lowest and best bidder on any alternate or to reject any or all bids; and to execute the same for and on behalf of the City.

Section 17. The City Engineer is hereby authorized and directed to supervise and manage the collection and disposal of garbage, rubbish and certain trade waste hereunder and to provide and supervise places for the disposal thereof and to supervise the handling and placing of earth cover and shall have general charge of and supervision over the administration and enforcement of this ordinance.

Section 18. If any section, subsection, subdivision, sentence, clause or phrase of this ordinance is for any reason held to be unconstitutional, or void, such decision shall not affect the validity of the remaining portions thereof.

Section 19. Violation of, or failure to comply with, any penal provision of this ordinance shall, upon conviction thereof, be punishable by a fine of not more than Three Hundred Dollars ($300.00), or by imprisonment in the City Jail for a period of not exceeding ninety (90) days, or by both such fine and imprisonment.

Section 20. That as of January 1, 1958, Ordinance No. 80726, entitled:

> AN ORDINANCE relating to the public health and sanitation, providing for and regulating the keeping, collection, removal and disposal of garbage and refuse and authorizing the Board of Public Works to enter into a contract for the same, and repealing Ordinance Nos. 63133, 67982, 72792 and 75991,

approved February 6, 1952, and all other ordinances or parts of ordinances in conflict herewith, are hereby repealed.

Section 21. 30-day ending.

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THE CITY OF SEATTLE, DEPARTMENT OF PUBLIC WORKS

INSTRUCTIONS TO BIDDERS, PROPOSAL, SPECIFICATIONS AND CONTRACT FOR GARBAGE, RUBBISH, AND CERTAIN TRADE WASTE COLLECTION, OPERATION AND MAINTENANCE OF THE VARIOUS DISPOSAL SITES AND THE PROVIDING AND PLACING OF EARTH COVER AT THE VARIOUS DISPOSAL SITES IN THE CITY OF SEATTLE

As authorized by Ordinance No. 86373

Prepared by the City Engineer July 9, 1957

R. W. MORSE
City Engineer

J. ROBERTSON
Assistant City Engineer

Examined and approved by the Board of Public Works July 10, 1957.

Attest:
E. G. HENRY Secretary R. W. MORSE
Chairman

INSTRUCTION TO BIDDERS

Sealed proposals for this work will be received by the Board of Public Works of the City of Seattle until 2:00 o'clock p.m., Wednesday September 11, 1957 in Room 512, County-City Building.

Bidders shall make proposals on the basis of furnishing equipment for carrying on the collections set forth in the special specifications attached hereto. All bids shall be accompanied by a certified check payable to the order of the City Comptroller, or by a bid bond approved as to form by the Corporation Counsel, for a sum of FIFTY THOUSAND AND 00/100 DOLLARS ($50,000.00). If the contract is let, all checks shall be returned to the bidders, except that of the successful bidder, which shall be retained until a contract is entered into between the bidder and the City in accordance with such bid. If the said bidder fails to enter into such contract in accordance with his bid within ten days from the date at which he is notified that he is the successful bidder, the said check and the amount thereof shall be forfeited to the City; or, if a bid bond accompanied the bid, the necessary legal steps will be taken by the City to recover the penalty of the bond.

Before such contract between the successful bidder and the City shall be valid or binding against the City of Seattle, the contractor shall enter into a joint and several bond with the City of Seattle as provided in the specifications attached hereto.

All payments for the work done under the special specifications attached hereto shall be made by warrants drawn on THE GENERAL FUND, and not otherwise.

The work embraced in the following Proposal and Contract shall be under the jurisdiction of the City Engineer. It shall begin on January 1, 1958, and shall run for a period of five years to December 31, 1962.

We call your attention to Chapter 282, Laws of Washington, 1957, regarding the rights of franchise or permit holders for garbage collection and/or disposal within areas which may be annexed to the City (See Section 42.0 of the special specifications).

Permission will not be given for the withdrawal or modification of any bid or proposal.

Bids for this contract must be made upon the printed blanks provided therefor by the City Engineer, without interlineation or amendment and bidders must submit a bid on each item, which includes a bid for each year of the contract, or their bid will not be considered.

Bids will not be received if detached from the form of contract with which they are bound, nor shall any of the accompanying papers be detached therefrom, but the entire package must be unbroken, in good order and enclosed in a sealed envelope, endorsed with the name of the bidder and the name of the work.

Quantities listed on the proposal blanks are for the purpose of comparing bids only.

Bidders are notified to examine thoroughly these instructions, the proposal, the form of contract, and specifications. If there be any doubt or obscurity as to meaning of the same, or any doubt as to the adequacy of proposed equipment, intending bidders shall ask the City Engineer for an explanation before submitting their proposal.

PROPOSAL

Seattle, Washington Sept. 11, '57

TO THE BOARD OF PUBLIC WORKS OF THE CITY OF SEATTLE:

The undersigned hereby certifies as follows:

That they have personally and carefully examined the specifications, form of contract and instructions for the work to be done in GARBAGE, RUBBISH, AND CERTAIN TRADE WASTE COLLECTION, OPERATION AND MAINTENANCE OF THE VARIOUS DISPOSAL SITES AND THE PROVIDING AND PLACING OF EARTH COVER AT THE VARIOUS DISPOSAL SITES IN THE CITY OF SEATTLE under Ordinance No. 86373:

That they have made examination of the points of origin and places of disposal of the garbage, rubbish and certain trade waste to be collected, and fully understand the character of the work to be done and the manner in which payment is to be made:

That having made the necessary examinations, the undersigned hereby propose to furnish all materials, vehicles, plant, equipment and facilities, and to perform all labor which may be required to do said work during the time fixed and upon the terms and conditions provided in the said specifications, contract and instructions, at the following prices, to wit:

Certified Check Enclosed $

Bid Bond Enclosed $50,000

Item No.	Quantity	Bid Unit	Bid Unit Price Dollars Cts.	Unit of Measure
1	572,000 Individuals (See Sec. 36.0 of the Specifications.)	Complete Collection and Disposal of Garbage, Rubbish, and certain Trade Waste, as specified for One Individual for the Calendar Year 1958, at	(Words and Figures) $2.83	Per One Individual
2	572,000 Individuals (Estimated Quantity for Comparing Bids Only.) See Sec. 36.0 of the Specifications.	Complete Collection of Garbage, Rubbish and certain Trade Waste, as specified for One Individual for the Calendar Year 1959, at	(Words and Figures) $2.91	Per One Individual

Item No.	Quantity	Bid Unit	Bid Unit Price Dollars Cts.	Unit of Measure
3	572,000 Individuals (Estimated Quantity for Comparing Bids Only.) See Sec. 36.0 of the Specifications.	Complete Collection and Disposal of Garbage, Rubbish, and certain Trade Waste, as specified for One Individual for the Calendar Year 1960, at	(Words and Figures) $3.00	Per One Individual
4	572,000 Individuals (Estimated Quantity for Comparing Bids Only.) See Sec. 36.0 of the Specifications.	Complete Collection and Disposal of Garbage, Rubbish, and certain Trade Waste, as specified for One Individual for the Calendar Year 1961, at	(Words and Figures) $3.10	Per One Individual
5	572,000 Individuals (Estimated Quantity for Comparing Bids Only.) See Sec. 36.0 of the Specifications.	Complete Collection and Disposal of Garbage, Rubbish, and certain Trade Waste, as specified for One Individual for the Calendar Year 1962, at	(Words and Figures) $3.20	Per One Individual
6	350,00 Cubic Yards (Estimated Quantity for the Purpose of comparing bids only.)	Earth for Cover for the Calendar Year 1958, at	(Words and Figures) $0.70	Per Cubic Yard
7	350,000 Cubic Yards (Estimated Quantity for the Purpose of Comparing bids only.)	Earth for Cover for the Calendar Year 1959, at	(Words and Figures) $0.75	Per Cubic Yard

Item No.	Quantity	Bid Unit	Bid Unit Price Dollars Cts.	Unit of Measure
8	350,000 Cubic Yards (Estimated Quantity for the Purpose of Comparing Bids Only.)	Earth for Cover for the Calendar Year 1960, at	(Words and Figures) $0.80	Per Cubic Yard
9	350,000 Cubic Yards (Estimated Quantity For the Purpose of Comparing Bids Only.)	Earth for Cover for the Calendar Year 1961, at	(Words and Figures) $0.95	Per Cubic Yard
10	350,000 Cubic Yards (Estimated Quantity For the Purpose of Comparing Bids Only.)	Earth for Cover for the Calendar Year 1962, at	(Words and Figures) $0.95	Per Cubic Yard

Address 912 Dexter

Seattle Disposal Company
Contractor

Tel. No. SE. 3340

By /s/ Josie Razore
(Partner)

ht:8-12-57

ADDENDUM NO. 1

GARBAGE COLLECTION & DISPOSAL SERVICES

ORDINANCE NO. 86373

PAGE C-21—SECTION 50.0 PERFORMANCE BOND

Amend the second paragraph of the above Sections to read as follows:

The condition of which bond shall be that the contractor shall fully and faithfully perform all conditions of the contract and these specifications; shall pay anyone who may perform or cause to be performed any work or labor, or furnish or cause to be furnished any skill, labor, equipment or material in the execution of such contract.

ROY W. MORSE
City Engineer
By
J. ROBERTSON
Assistant City Engineer

BID OPENING SEPTEMBER 11, 1957

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pm:8-29-57

ADDENDUM NO. 2

GARBAGE COLLECTION & DISPOSAL SERVICES

ORDINANCE NO. 86373

PAGE C-8—SECTION 12.0 OWNERSHIP OF EQUIPMENT

Amend the above Sections to read as follows:

All vehicles and equipment used in the performance of this contract shall be wholly owned by the contractor; provided, leasing or rental agreements may be allowed where approved by the Board of Public Works prior to submission of bids and conditional sale contracts, mortgages, or other contractual arrangements for financing the purchase of such equipment may be allowed where approved by the Board of Public Works prior to execution of this contract. All such leasing or rental agreements shall provide that in the event of default of this contract, or of such leasing or rental agreement, the City, at its option, shall have the right to take possession of and operate vehicles and equipment covered by such leasing or rental agreement for the unexpired term of this contract. Any such conditional sales contract, mortgage, or other contractual arrangements for financing purchase of such equipment shall provide that in event of default of this contract or of such conditional sales contract, mortgage, or other contractual arrangement, the right to the possession and use of such vehicles, equipment and facilities may be taken by the City for the unexpired term of this contract. No further encumbrance shall be placed upon any of such equipment without the approval of the Board of Public Works, save that the contractor may, without such consent, mortgage or otherwise encumber said vehicles, equipment and facilities for the purpose of enabling the contractor to replace the same or add thereto.

ROY W. MORSE
City Engineer
By
J. ROBERTSON
Assistant City Engineer

BID OPENING SEPTEMBER 11, 1957

SPECIAL SPECIFICATIONS

FOR

GARBAGE, RUBBISH AND CERTAIN TRADE WASTE COLLECTION, OPERATION AND MAINTENANCE OF THE VARIOUS DISPOSAL SITES AND THE PROVIDING AND PLACING OF EARTH COVER AT THE VARIOUS DISPOSAL SITES IN THE CITY OF SEATTLE

Ordinance No. 86373

1.0 GENERAL DESCRIPTION:

The work to be performed consists of the complete collection of all garbage, rubbish and certain trade waste accumulated in the City of Seattle; the operation and maintenance of the various disposal sites; and the providing and placing of earth cover at such disposal sites.

It shall be the contractor's duty to report, in writing, any violations of such ordinance in respect to the preparation and placement of garbage, rubbish, and certain trade waste to the City Engineer. The City Engineer shall be sole and final judge as to such preparation and placement.

2.0 COLLECTION SCHEDULE:

Garbage, rubbish and certain trade waste, as defined by Ordinance No. 86373, shall be collected from all premises, public and private, docks, ferry and passenger boats lying at dock and from all public park concessions, except from military establishments, military housing projects, or from the University of Washington campus.

Until ordered by the City Engineer, the contractor shall not collect "swill," as defined in Ordinance Nos. 60085 and 80451. Thereafter, the contractor shall collect all garbage as defined in Ordinance No. 86373, including such "swill." No extra payment will be made for collecting such "swill."

The collection of garbage, rubbish and certain trade waste shall be made in accordance with the following schedules:

Schedule "A": Collections shall be made once each day, except Sundays, between the hours of 1:00 a.m. and 12:00 noon.

Schedule "A" shall apply to the central downtown business district described as follows:

Beginning at 1st Avenue and Lenora Street; thence westerly along Lenora Street to Elliott Bay; thence southerly along the shore of Elliott Bay and the East Waterway to West Spokane Street; thence easterly along West Spokane Street and Spokane Street to Airport Way; thence northerly along Airport Way to 9th Avenue South; thence northerly along 9th Avenue South to Jackson Street; thence westerly along Jackson Street to 5th Avenue South; thence northerly along 5th Avenue South and 5th Avenue to Madison Street; thence easterly along Madison Street to 7th Avenue; thence northerly along 7th Avenue to Seneca Street; thence easterly along Seneca Street to 9th Avenue; thence northerly along 9th Avenue to Lenora Street; thence westerly along Lenora Street to 1st Avenue. Both sides of all bordering streets shall be included in this district.

Schedule "B": Collections shall be made once each day, except Sundays, between the hours of 5:00 a.m. and 6:00 p.m.

Schedule "B" shall apply to:

The Northgate Shopping Center; the University Village Shopping Center; the University business district bounded by 12th Avenue Northeast, 15th Avenue Northeast, Campus Parkway and East 50th Street; the Ballard business district bounded by West 56th Street, 20th Avenue Northwest, Vernon Place, Shilshole Avenue and 27th Avenue Northwest; on Bothell Way from East 120th Street to East 145th Street; on North Broadway from Denny Way to East Roy Street and the district in West Seattle bounded by 44th Avenue Southwest, 42nd Avenue Southwest, West Edmunds Street and West Oregon Street. Both sides of all bordering streets are included in these districts.

Schedule "C": Collections shall be made not less than three times per week between the hours of 7:00 a.m. and 6:00 p.m. If, in the opinion of the City Engineer more collections are necessary, he may require up to six collections per week.

Schedule "C" shall apply to the following suburban business districts:

[Description of 48 suburban business districts omitted from this appendix.]

Schedule "C" shall also apply, in all other districts, to hospitals, hotels, apartments, large boarding houses, fraternity or sorority houses; but shall not apply to motels, rooming houses, bungalow courts, garden courts, trailer parks, or housing projects.

Schedule "D": Collections shall be made not less than two times per week between the hours of 7:00 a.m. and 6:00 p.m. If, in the opinion of the City Engineer more collections are necessary, he may require up to six collections per week.

Schedule "D" shall apply to the following small business districts:

[Description of five small business districts omitted from this appendix.]

Schedule "D" shall apply to motels in all other districts.

Schedule "E": Collections shall be made once each week between the hours of 7:00 a.m. and 6:00 p.m.

Schedule "E" shall apply to all residential districts and shall include rooming houses, bungalow courts, garden courts, trailer parks and housing projects.

Whenever any district shall develop or whenever the contractor is required to collect within any area annexed to the City of Seattle after the effective date of this contract, the City Engineer shall determine the collection schedule for such district or annexed area. The contractor shall collect in accordance with these schedules at no additional cost to the City, except as provided herein for annexations.

3.0 MEANING OF TERMS:

The meaning of terms and words used herein shall be as defined in Ordinance No. 86373.

4.0 EMPLOYEES TO BE COURTEOUS, ETC.:

The contractor shall require all employees to be courteous at all times and not to use loud or profane language and to do their work as quietly as possible.

5.0 EMPLOYEES TO USE WALKS:

Employees, in collecting garbage, rubbish and certain trade waste shall follow the regular walks for pedestrians while on private property, returning to the street or alley after replacing the empty cans. They shall also replace all covers and close all gates opened by them.

6.0 EMPLOYEES NOT TO TRESPASS:

Employees shall not trespass or loiter, cross property to adjoining premises, or meddle with property which does not concern them.

7.0 LOADING:

Extra care shall be taken in the loading and transportation of garbage, rubbish or trade waste so that none of the material to be collected is left either on private property or on the streets or alleys. Any garbage, rubbish or trade waste left on private property or on streets or alleys by the contractor shall be cleaned up by the City Engineer, and the cost of doing same shall be deducted from the special fund created by Section 32.0.

The contractor shall be responsible for the cleaning of all earth or debris placed, spilled or tracked on any street, alley or public place by any of his equipment, and if the contractor fails to clean the same, within two hours after written notice is served by the City Engineer, the City Engineer may cause such streets to be cleaned and deduct the cost thereof from the special fund created in Section 32.0, notwithstanding the provision in Section 32.0 relative to twenty-four-hour notice.

8.0 EMERGENCY COLLECTIONS:

Adequate provision shall be made by the contractor to take care of collections when garbage, rubbish, or certain trade waste have not been collected during the regularly scheduled trip. Special pickups for missed collections shall be made by the contractor when ordered by the City Engineer.

9.0 COLLECTION EQUIPMENT:

In collecting garbage, rubbish and certain trade waste under this contract, the contractor shall use all-metal, watertight, completely enclosed "packer" type bodies that are designed and manufactured for the collection of garbage and rubbish. These bodies shall be:

1. "Speed-packer" or "Load packer" as manufactured by Gar-Wood Industries;
2. "Roto-Pak" as manufactured by City Tank Corporation;
3. "Hydepak" as manufactured by Hyde Corporation;
4. "Leach" as manufactured by Elgin Corporation;
5. Heil "Colectomatic" as manufactured by Heil Company;
6. "Hydro E-Z" as manufactured by Hercules Galion Products;
7. "Pak-Mor" as manufactured by Pak-Mor Manufacturing;
8. "M-B-Packer" as manufactured by M-B Corporation;

or equal. The compacting mechanism in the body shall be capable of compressing the collected material to one-half or less its original volume. The number of collection vehicles furnished by the contractor shall be sufficient for the collection of all garbage, rubbish and certain trade waste. The decision of the City Engineer as to the number and sufficiency of the vehicles shall be final and binding upon the contractor.

If there be any doubt, by the contractor whether his proposed equipment is satisfactory or not, he should acquire prior approval from the City Engineer.

10.0 DISPOSAL SITE EQUIPMENT:

The contractor shall provide equipment at the various disposal sites that shall be of sufficient weight and size to be capable of placing all material that is brought to the disposal site. The minimum sizes of acceptable equipment are shown below:

A disposal site which handles 0-1000 cubic yards per day	Caterpillar D-6 or equal
A disposal site which handles 1000-2000 cubic yards per day	Caterpillar D-7 or equal
A disposal site which handles over 2000 cubic yards per day	Caterpillar D-8 or equal

11.0 EARTH HAULING EQUIPMENT:

The contractor shall provide sufficient equipment to supply the amount of earth specified herein.

The contractor shall identify and number such equipment in a manner approved by the City Engineer.

12.0 OWNERSHIP OF EQUIPMENT:

All vehicles and equipment used in the execution of this contract shall be wholly owned by the contractor; except that a leasing or rental agreement may be allowed if approved by the Board of Public Works prior to submission of bids. Any leasing or rental agreement shall provide that in the event of default of this contract, or of such leasing or rental agreement, the City, at its option, shall have the right to take possession of and operate vehicles and equipment covered by such leasing or rental agreement for the unexpired term of this contract.

Before the contract is signed, the contractor shall furnish evidence satisfactory to the Board of Public Works that in event of default the right to the possession and use of such vehicles, equipment and facilities may be taken by the City, notwithstanding the terms of conditional sale contracts, mortgages or incumbrances. No future incumbrance shall be placed upon the said property without the approval of the Board of Public Works, save that the contractor may, without such consent, mortgage or otherwise encumber said vehicles, equipment and facilities for the purpose of enabling the contractor to replace the same or add thereto.

13.0 WASH RACKS:

The contractor shall provide adequate wash racks, approved as to number, location and type by the City Engineer, to take care of equipment washing. These wash racks shall be used for all washing of equipment and be kept in a clean, sanitary condition.

14.0 PAINTING OF VEHICLES:

Collection vehicles shall be painted white and numbered consecutively from one upward, and shall have the contractor's name and the number of the vehicle painted in letters of a contrasting color, at least four inches high, on each side of each vehicle, and the number painted on the rear. No advertising shall be permitted other than the name of the contractor. All vehicles shall be kept in a clean and sanitary condition; and all collection vehicles shall be steam cleaned, inside and out, at least once each week. Repainting of all vehicles shall be done not less often than every 2½ years.

15.0 PARKING OF VEHICLES:

The contractor shall not use property in or adjoining that zoned as residence or the various disposal sites for the parking, standing, washing, cleaning, or storing of his vehicles or equipment without the approval of the City Engineer.

16.0 METHOD OF DISPOSAL:

The contractor shall deliver all garbage, rubbish and trade waste collected under this contract to the disposal sites provided by the City which are most convenient to the district from which collection is made, as may be determined by the City Engineer.

All garbage, rubbish and trade waste shall be dumped at the bottom or toe of the face of the lift and then pushed into place by a bulldozer up an incline to the top of the lift. At the end of each day the grade of such incline shall be not less than fifteen per cent. As the garbage, rubbish and trade waste is placed, it shall be thoroughly compacted, and all boxes and cartons shall be completely collapsed. The height and width of any lift shall be as directed by the City Engineer. The lift shall progress in length not less than five lineal feet per day, or as directed by the City Engineer.

No garbage, rubbish or trade waste shall be dumped on the top of the lift unless the bottom surface is not suitable for equipment operation. If the bottom surface is not suitable for equipment operation, a platform may be constructed by dumping garbage, rubbish or trade waste and pushing it ahead with a bulldozer to a thickness that will readily support all equipment. This platform shall be covered with earth only to a sufficient depth to protect tires and equipment. The size of the platform shall be only sufficient to permit free movement of equipment.

The sides of each lift shall be raked and left with a slope when and as may be directed by the City Engineer. Such slopes shall have a smooth surface and be kept free of litter.

Before earth covering is placed on the lift, all surfaces and slopes must be compressed by the bulldozer to a reasonable smooth, hard, compact surface with no soft, low or high points existing.

The earth covering shall be delivered to the top side of the lift, and shall be put in final place by the bulldozer. Sufficient earth shall be stockpiled at the top side of the lift to enable the bulldozer operator to completely cover and enclose each lift each day.

All active lifts at the City's disposal sites shall be completely covered with earth at the end of each day's operation, unless otherwise directed by the City Engineer.

The City Engineer shall be the sole judge as to the adequacy of earth covering on each lift at the various sites.

The contractor shall provide and maintain all access routes over the various disposal sites.

17.0 DISPOSAL SITES:

The various disposal sites presently provided by the City of Seattle are:

Site No. 1: Designated "RAVENNA"—located in the general vicinity of East 45th Street and Montlake Boulevard.

Site No. 2: Designated "INTERBAY"—located in the general vicinity of 16th Avenue West and West Armour Street.

Site No. 3: Designated "RAINIER VALLEY"—located in the general vicinity of 44th Avenue South and Genesee Street.

Site No. 4: Designated "WEST SEATTLE"—located in the general vicinity of Harbor Avenue Southwest and West Hanford Street.

Attached hereto is a map of the City of Seattle showing the approximate location of such disposal sites.

18.0 TOILET FACILITIES:

The contractor shall provide washing and toilet facilities on the disposal sites for his employees. These facilities shall be located as directed by the City Engineer. Their design and construction shall be approved by the Director of Public Health and shall be kept painted and in a clean and sanitary condition.

19.0 EARTH COVERING:

The total volume of earth necessary for the contract period is estimated to be 1,750,000 cubic yards, more or less; the volume necessary to properly cover the various disposal sites in any year is estimated to be 350,000 cubic yards, more or less.

All earth shall be furnished and placed by the contractor at the bid price per cubic yard.

The contractor shall be permitted to stockpile earth on the disposal sites only when approved by the City Engineer. No payment for this material shall be allowed until it is actually placed on the fill and then only in the manner herein described.

The earth used for covering shall be clean, free of roots, stumps, chunks of concrete or other foreign material and shall contain not more than fifty per cent blue clay. All cover material shall be subject to inspection by the City Engineer. If the cover material does not meet the above specifications, it may be rejected by the City Engineer.

20.0 COVERING OF FILLS BY CITY ENGINEER:

If the contractor shall fail to promptly cover any disposal site or to correct any defect as directed within twenty-four hours after notice in writing is given by the City Engineer, the City Engineer shall cause the same to be done and the cost of so doing shall be paid from money deposited by the contractor as herein provided.

21.0 DISPOSAL SITE PERSONNEL:

The contractor shall assign dump men to duty at each disposal site on such days and during such hours that garbage, rubbish and certain trade waste covered by this contract is being dumped on said disposal site and keep bulldozer equipment and operators at each disposal site during such times. The duty of such employees shall be to supervise and maintain the disposal sites in a manner satisfactory to the City Engineer.

The contractor shall allow the dumping of all vehicles hauling in trade waste, at every disposal site, when directed by the City Engineer. Such trade waste shall be dumped along with the regular garbage, rubbish and certain trade waste and placed, compacted and covered by the contractor in the same manner. The City Engineer shall be the sole judge as to what material shall be accepted on the various disposal sites.

22.0 FIRES AT DISPOSAL SITES:

The contractor shall provide the necessary water lines at each disposal site, as may be directed by the City Engineer. Sufficient fire fighting equipment, properly housed, shall be kept readily available at all times at each disposal site to effectively and promptly stop all fires at said disposal sites.

The contractor shall extinguish immediately any fires on any disposal site (not City fire or refuse dumps) and he shall pay to the City the sum of One Hundred Dollars per day for each day or part of a day in excess of a period of eight hours that such fire shall continue to burn and the City is called upon to extinguish the same. Such sum shall be deducted from any moneys due or to become due to him from the City. Such sum shall in no way be construed as a penalty, but it is agreed between the City and the contractor as a condition precedent to the signing of the contract that such sum shall be the liquidated damages to cover the cost incurred by the City through the use of its fire apparatus, its servants, agents and employees in extinguishing said fires.

Any earth required to smother out fires or to restore the surface of the disposal site to grade where a drop was due to fires shall be furnished and placed by the contractor at his own expense.

23.0 SPRINKLING OF DISPOSAL SITES:

During periods of dry weather the contractor shall be required to water sprinkle the active face of the lift prior to daily covering and at such other times as may be directed by the City Engineer.

24.0 SALVAGE:

No salvaging of any nature under any circumstances at any of the City's disposal sites will be permitted.

25.0 MAINTENANCE OF DISPOSAL SITES:

The contractor shall be required to maintain and keep free of litter and other foreign material all lifts and access routes at the disposal site. He shall also be required to pick up all paper blown from the active lift.

The contractor shall, when directed by the City Engineer, use an approved disinfectant and deodorant at all disposal sites, in sufficient quantities to control any fly or insect problem.

26.0 MEASUREMENT:

Prior to use in performance under this contract, the City Engineer shall measure the capacity of all vehicles to be used for the delivery of earth. The basis for this measurement shall be the strike-off capacity of the vehicles. The capacity, as measured by the City Engineer, shall be used to compute payment under this contract. However, in no event shall the contractor be paid for any excess on a load which exceeds the gross vehicle weight as stated on the truck vehicle license application.

The amount of earth delivered each month to the various disposal sites shall be computed by the City Engineer and his computation shall be final and binding on the contractor.

27.0 EVENING AND SATURDAY COLLECTIONS:

All garbage, rubbish and trade waste collected on Monday through Friday shall be delivered to the disposal site by 3:00 p.m. of the day on which it is collected. The City Engineer shall designate certain disposal sites for use by the evening and early morning collection routes.

All garbage, rubbish and trade waste collected on Saturdays shall be delivered by 11:00 a.m. on Saturday to the disposal site designated by the City Engineer.

28.0 REPORT AND MAPS:

The contractor shall furnish an annual report, at the end of each calendar year, to the City Engineer showing the number of loads of garbage, rubbish and certain trade waste hauled by him to each disposal site during the year, the approximate number of cubic yards per load and the total number of cubic yards of garbage, rubbish and certain trade waste hauled to each disposal site for each month.

The contractor shall also outline, on maps furnished by the City Engineer, his collection routes and the disposal sites to which they haul. These maps shall be brought up to date every six months by the contractor and at such additional times that the City Engineer shall require the same.

29.0 CONTRACTOR'S TARIFF RATES:

The contractor shall supply the City Engineer with a complete copy of his rates, as approved or fixed by the Washington State Public Service Commission, for the collection of material not covered by this contract or for garbage, rubbish or certain trade waste not placed or prepared for collection in accordance with Ordinance No. 86373.

The contractor shall also inform the City Engineer of his intention to revise such rates.

30.0 CHANGE OF DISPOSAL SITES:

The contractor shall use the locations specified herein for the disposal of garbage, rubbish and trade waste until otherwise ordered by the City Engineer.

When, in the opinion of the City Engineer, it becomes necessary, for any reason, to discontinue the use of any of the disposal sites hereinbefore specified or to acquire a new disposal site or disposal sites, the contractor shall not be entitled to any damages by reason thereof except in the amounts hereinafter prescribed.

When a new disposal site is acquired or a specified disposal site is abandoned and an alternate disposal site is designated for use, the contractor shall order delivery of garbage, rubbish and certain trade waste from such collection routes to such new or alternate disposal site as may be directed by the City Engineer.

The amount of increase or decrease in compensation due the contractor for such changes in disposal sites shall be computed as follows:

A. The City Engineer shall measure the distances, along the most direct route on usable streets, from the geographical center of each collection route in the City to the entrance of the disposal site to which said collection routes normally haul. The geographical center of said collection routes shall be determined by the City Engineer from the route maps provided by the contractor. Such distances shall be averaged and, for convenience in computation, this average shall be called distance "A."

B. Whenever a disposal site is abandoned, the City Engineer shall determine a new or alternate disposal site for collection routes using the disposal site to be abandoned. The City Engineer shall also measure the distance, along the most direct route on usable streets, from the geographical center of the routes which will use the new or alternate disposal site, to the entrance of the new disposal site. The average of these distances shall be called "B."

The difference in miles between "A" and "B" multiplied by the number of loads thus hauled, as determined by the City Engineer, shall equal the number of load-miles.

If the distance "A" is less than the distance "B," increased compensation to the contractor shall be made at $0.45 for each load-mile.

If the distance "A" is greater than the distance "B," the City shall deduct from the contractor's monthly estimate an amount equal to the number of load-miles at $0.45 for each load-mile.

C. Whenever a new or additional disposal site is acquired by the City, the City Engineer shall determine which collection routes shall use such new disposal site.

The City Engineer shall also measure the distance, along the most direct route on usable streets, from the geographical center of the routes which will use the new or additional disposal site, to the entrance of such new or additional disposal site. The averages of these distances shall be called "C."

The difference in miles between "A" and "C" multiplied by the number of loads thus hauled, as determined by the City Engineer, will equal the number of load-miles.

If the distance "A" is less than the distance "C," increased compensation to the contractor shall be made at $0.45 for each load-mile.

If the distance "A" is greater than the distance "C," the City shall deduct from the contractor's monthly estimate an amount equal to the number of load-miles at $0.45 for each load-mile.

31.0 BRIDGE CLOSURES:

If, at any time during the life of this contract any bridge shall be closed to traffic for more than thirty consecutive days and such closure will, in the opinion of the City Engineer, result in a substantial increase in the contractor's cost, adjustment in the amount of compensation paid to the contractor shall be made in such amount as the City Engineer shall deem fair and equitable, based on the increased number of load-miles traveled, at $0.45 per load-mile.

32.0 SPECIAL FUND:

Within ten days of the execution of this contract, the contractor shall be required to make a cash deposit of Five Thousand and 00/100 Dollars ($5,000.00) to guaranatee the immediate compliance with the requirements of this contract and compliance within a period of twenty-four hours with any written order of the City Engineer in respect thereto. Said cash shall be deposited in the City Treasury in a special fund. Upon failure of the contractor to take the necessary action on said written order, the City Engineer shall cause the work to be done and payment therefor to be made by warrants drawn upon such fund.

The City Engineer shall deduct the amount of any such sums spent in any month from payments due the contractor and deposit the same in the special fund to the end that said fund shall be constantly maintained at its original sum.

33.0 PAYMENT OF DISPOSAL FEES:

The contractor agrees to pay to the City the disposal fees authorized by

Ordinances No. 83701 and No. 83880. These fees shall not apply to garbage, rubbish, and certain trade waste collected under these specifications by the contractor and paid for by the City. If material not covered by the specifications is collected in the course of regular contract collections, the contractor shall furnish the City with a list of premises from which such material is collected. Such list, to be furnished quarterly, shall state the name of the premises, the frequency of collection, and the volume of material collected at each collection. The City Engineer shall compute the volume of this material on a truck load basis and apply the fee prescribed by Ordinances No. 83701 and No. 83880. This fee shall be due and payable by the first of each month. When full or partial loads of material not covered by this contract are collected separately and delivered separately to the disposal site, the full fee shall apply.

34.0 BILLS OF CITY DEPARTMENTS—HOW PAID:

The contractor shall pay in cash all bills rendered against him by any City Department. If the contractor shall fail to pay any such bill, within thirty days, the City Engineer may pay such bills and deduct the amount thereof from moneys in the special fund created in Section 32.0, or from any monthly payments due the contractor.

35.0 CONTRACTOR'S OFFICE:

The contractor shall be required to maintain an office provided with telephones and such attendants as may be necessary to take care of complaints, orders for special service, or to receive instructions.

36.0 METHOD OF DETERMINING PAYMENT:

Payments on this contract for the collection of garbage, rubbish and certain trade waste and for the operation and maintenance of the disposal sites shall be based on the bid unit price for the respective contract year. The product of the pertinent bid unit price and the population of the City of Seattle shall constitute the annual contract price for such collection and operation and maintenance.

In addition, payments on this contract for earth delivered shall be based on the price bid per cubic yard for the respective contract year.

It is agreed that for the purpose of determining payment to the contractor, for collection and the operation and maintenance of the disposal sites, the population of the City of Seattle within the limits existing January 1, 1958, shall be 572,000. For the purpose of this contract, this population figure, unless changed by annexation of and collection by the contractor in additional territory, shall be deemed correct until January 1, 1959. At that date this figure shall be revised to conform with the revised population figure as shown by the official population figures filed with the Secretary of the State of Washington on June 1, 1958, by the State Census Board, in accordance with Chapter 96, Laws of Washington, 1951. Annually, thereafter, on the first day of January, during the life of this contract, the population figure shall be revised in accordance with the population figure certified by the State Census Board to the Secretary of State in the June preceding the January the revision is made.

37.0 ANNEXATIONS:

If, during the life of this contract, additional territory in any amount whatsoever is acquired by the City through annexation the City reserves the right, upon ten-day written notice to the contractor, to order the contractor to make collections in such annexed area in accordance with all provisions of these specifications and at the price set forth herein. (See Chapter 282, Laws of Washington, 1957.)

Payment for such collection and the operation and maintenance of the disposal sites therein will be determined by multiplying the population of said annexed area, as determined in the manner prescribed by Section 5, Chapter 248, Laws of Washington, 1951, by the unit contract price per capita for the applicable year. One-twelfth of the product of these figures shall be paid monthly in the same manner as other payments are made for work performed by the contractor, commencing from the date the annexation becomes effective to the next contract revision date, as specified in Section 36.0, in which the population of said annexed area is included in the official population of the City, as determined by the State Census Board.

This payment shall constitute full compensation for all work performed in any annexed area, and the contractor shall have no other claim for additional compensation by reason of such collection and operation and maintenance of the disposal sites attributable to such annexation.

38.0 ESTIMATES AND PAYMENTS:

During the life of this contract the City Engineer shall, on or about the second Wednesday of each month, issue an itemized statement of the sum due the contractor for the previous month's work. Said itemized statement shall state the sum due the contractor for the collection of garbage, rubbish and certain trade waste and for the operation and maintenance of the disposal sites, which sum shall equal one-twelfth of the amount due the contractor for the year in which such work is performed. Said itemized statement shall also contain an item of the amount due for earth placed upon the various disposal sites by the contractor during the prior month. In addition, said itemized statement shall include items of amounts due, if any, for overhaul, annexations, or wage increase reimbursements.

After the issuance of said statement, the City Comptroller shall, on or about the fourth Wednesday of the month, deliver to the contractor warrants of an amount equal to such statements, less any sums retained to cover any verified claims filed with the City Comptroller, due to or arising out of this contract; and also less any sums that have been expended in accordance with Section 32.0 and Section 34.0.

39.0 FINAL PAYMENT:

Thirty days after the expiration of this contract, all moneys due the contractor held by the City in excess of a sufficient sum retained to cover any claims, verified or otherwise, filed with the City Comptroller, due to or arising out of this contract; a sufficient sum to meet and discharge the claims of material, equipment and supply men; a sufficient sum to meet and discharge the claims of laborers who have filed their claims with the City Comptroller, together with a sum sufficient to defray the costs of action, shall be paid to the said contractor; provided, however, that said excess shall first be applied in payment of any bills due the City of Seattle or any of its departments, as shown by the final statement.

40.0 CONTRACTOR TO MAKE EXAMINATION:

The contractor shall make his own examination, investigation and research regarding the proper method of doing the work, and all conditions affecting the work to be done and the labor, equipment and materials needed thereon and the quantity of the work to be performed, and the contractor agrees that he has satisfied himself by his own investigation and research regarding all of such conditions, and that his conclusion to enter into the proposed contract is based upon such investigation and research, and that he shall make no claim against the City because any of the estimates, statements or interpretations made by any officer or agent of the City may prove to be in any respect erroneous.

The contractor assumes the risk of all conditions foreseen or unforeseen and agrees to complete the work without additional compensation under whatever circumstances which may develop other than as herein provided.

41.0 QUANTITIES FURNISHED TO BIDDERS:

Quantities listed on the proposal sheet are for the purpose of comparing bids only and may be increased or diminished. Payments shall be made only for actual quantities delivered to the various disposal sites and at the price bid; provided, however, that no payment shall be made for unauthorized work or material not specified.

42.0 PERMITS:

The contractor shall take out and pay for any permits required by the City. In particular this pertains to permits for all curb crossings and concrete walk crossings.

The contractor shall be obligated to protect all public and private utilities whether occupying street or public or private property. If such utilities are damaged by reason of the contractor's operations under this contract, he shall repair or replace same or, failing to do so promptly, the City Engineer shall cause repairs or replacements to be made and the cost of doing so shall be paid from moneys deposited in the special fund as provided in Section 32.0.

43.0 ASSIGNMENT OF MONEYS BY THE CONTRACTOR:

No assignment or pledge of the moneys to become due under this contract shall be made without the written approval of the surety on the performance bond and the consent of the Board of Public Works being first obtained and endorsed thereon. Such assignment or pledge, however, shall not release the contractor or his sureties from any obligations or liabilities arising under or because of this contract.

44.0 NO ASSIGNMENT OR SUBLETTING OF CONTRACT:

No assignment or subletting of all or any portion of the work under these specifications shall be permitted. The contractor alone, subject to the provisions of his performance bond, shall be held responsible for the full and faithful performance of this contract.

45.0 WORKMEN:

All workmen employed shall be competent and skilled in the performance of the work to which they may be assigned. Failure or delay in the performance of this contract due to the contractor's inability to obtain workmen of the number and skill required shall constitute a default of the contract.

Whenever the contractor is not present on the work, orders may be given by the City Engineer to the superintendent or foreman, who may have immediate charge thereof. If any person employed on the work shall refuse or neglect to obey the direction of the City Engineer, or in the opinion of said City Engineer shall be incompetent, unfaithful, disorderly, or otherwise unsatisfactory, he shall, upon the order of the City Engineer, be at once discharged and not again employed upon any part of the work. Any person so discharged shall, however, have the right to appeal to the Board of Public Works, whose decision shall be final and conclusive.

46.0 LIABILITY INSURANCE:

The contractor shall provide and maintain in full force and effect during the entire term of this contract, regular Contractor's Public Liability Insurance, with the City as an additional insured, providing for a limit of not less than Two Hundred Fifty Thousand Dollars ($250,000.00) for all damages arising out of bodily injuries to or death of one person, and subject to that limit for each person, a total limit of not less than Five Hundred Thousand Dollars ($500,000.00) for all damages arising out of bodily injuries to or death of two or more persons in any one accident; and regular Contractors' Property Damage Liability Insurance providing for a limit of not less than Fifty Thousand Dollars ($50,000.00) for all damage arising out of injury to or destruction of property in any one accident, and, subject to that limit per accident, a total limit of not less than One Hundred Thousand Dollars ($100,000.00) for all damages arising out of injury to or destruction of property during the policy period.

Such policy shall provide for ten days' notice to the City of any change, cancellation, or lapse of such policy.

The contractor shall further guarantee to save harmless and indemnify the City of and from any and all loss, damage, claims, suits, judgments and recoveries which may be asserted, made or may arise or be had, brought or recovered against the City by reason of any of the foregoing claims, except such as are caused by the existence of the disposal sites at the locations specified or contemplated in the contract; and that he shall immediately appear and defend the same as his own cost and expense.

Prior to the effective date of this contract, the contractor shall file a copy of such policies with the Board of Public Works.

47.0 PREVAILING WAGES:

Pursuant to Chapter 63, Session Laws of the State of Washington 1945, the contractor awarded this contract shall pay his employees on such work not less than the prevailing hourly scale of wages for the same trade or occupation in the City of Seattle.

In the event any dispute arises as to whether the rates paid are the prevailing rates for this locality, and the dispute cannot be adjusted by the parties involved, the matter shall be referred for arbitration to the Director of the Department of Labor and Industries of the State of Washington and his decision therein shall be final and conclusive and binding on all parties in the dispute.

48.0 WAGE INCREASES FOR EMPLOYEES:

During the first contract year, all wage increases granted by the contractor, shall be paid solely by such contractor, with no reimbursement by the City. After the first contract year, the City shall reimburse the contractor for sixty per cent of any wage increases granted to collectors employed on work covered by this contract. The remaining forty per cent of such increases shall be paid solely by the contractor.

For the purposes of this section, the term "collectors" shall mean only those employees actually engaged in collecting garbage, rubbish and certain trade waste for which the City pays the contractor including both drivers and swampers. It shall not apply to mechanics, office employees, earth truck drivers, bulldozer operators, or any other employee.

The City Council reserves the right to be represented during any wage negotiations between the contractor and his employees or their representatives and it shall be the contractor's responsibility to notify the City Council of any such negotiations.

The contractor shall notify the City Engineer of all wage increases granted by such contractor to collectors, stating the previous wage scale, the increase granted, the new wage scale and the estimated man-hours per year on which the increase shall be paid.

The reimbursement to the contractor shall be determined by multiplying the increase granted by the man-hours worked per year. One-twelfth the product of these figures shall be paid monthly in the same manner as payments are made for other work performed by the contractor.

The reimbursements to the contractor shall not apply to any vacations, sick leave or any other payroll expense not directly involved in the collection of garbage, rubbish and certain trade waste nor to the payment of any overtime which the contractor may elect or be required to pay.

49.0 CONTRACTOR TO SUBMIT BOOKS:

At any and all times during the life of this contract, should the contractor request any adjustment in his bid price, any reimbursement for wage increases granted, or any other compensation other than the adjustments due to increases or decreases in population, he shall submit his books, accounts and a complete labor segregation between the collection for which the City pays the contractor and the private "fee" collection, to the Board of Public Works and the City Comptroller for complete examination.

50.0 PERFORMANCE BOND:

Before the contract between the successful bidder and the City shall be valid or binding against the City of Seattle, the contractor shall enter into a joint and several bond with the City of Seattle, for the use of said City, and also for the use of anyone who may perform or cause to be performed any work or labor, or furnish or cause to be furnished any skill, labor, equipment or material in the execution of such contract, which bond shall be signed by the contractor and two or more good and sufficient sureties or with a surety company as surety, and shall be in the amount of Three Hundred Fifty Thousand and 00/100 Dollars ($350,000.00), which bond shall at all times be kept in full force and effect.

The condition of which bond shall be that the contractor shall fully and faithfully perform all conditions of the contract and these specifications;

shall pay anyone who may perform or cause to be performed any work or labor, or furnish or cause to be furnished any skill, labor, equipment or material in the execution of such contract; and such bond shall provide that the full amount thereof shall be forfeited upon the contractor's failure to comply therewith.

51.0 PAYMENT FOR LABOR AND MATERIALS:

The contractor shall perform this contract according to the terms, conditions and stipulations herein, and shall pay as they become due, all just claims for all work and labor performed on or about said work, and all skill or labor and materials and equipment purchased for or furnished in the execution of the contract; and further, shall comply with all the provisions of State laws and with all the requirements of the charter and ordinances of the City and the amendments thereto. Any person furnishing supplies, equipment or materials or performing any work or labor on this contract that is not paid when due, may file with the City Comptroller a verified claim for such amount as is claimed to be due from the contractor. The City Comptroller shall withhold the amount of any such claims from payments due the contractor under this contract until such time as said claims are satisfied as prescribed by law.

If, at any time during the progress of the work, it shall appear to the City Comptroller that time checks or other evidences of indebtedness have been issued by such contractor, then the City Comptroller, upon presentation to him of such time checks or other evidence of indebtedness, shall issue to such labor claimants a warrant or warrants therefor upon the special fund created by the cash deposit hereinbefore mentioned. The City Comptroller shall charge the amount of all warrants so issued against the account of the contractor for this work and shall deduct the amount thereof, together with a penalty of ten per cent thereon, from the next or succeeding payment to be made to said contractor.

52.0 CONTRACTOR RESPONSIBLE FOR WORK DONE:

The contractor shall furnish for the prices bid all skill, labor, equipment and materials required for the complete performance of the contract, and shall fully perform the work in accordance with the specifications. He shall be responsible for the entire contract, but the acceptance of the work by the City Engineer shall not prevent the City from making claims against the contractor for any uncompleted or defective work. The fact that a representative of the City Engineer was present during the progress of any work shall not relieve the contractor from responsibility for defects discovered after the completion thereof.

53.0 EXTRA WORK:

If, for any reason, extra work should be ordered by the City Engineer, with the approval of the Board of Public Works, and a price for such work has not been agreed upon, it shall be paid for as follows:

For all labor and foremen in direct charge of the specific operation, the contractor shall receive an amount equal to the current wages paid such labor and foreman, for the time actually engaged in such work, plus an amount equal to twenty per cent thereof.

For all materials used, the contractor shall receive the actual cost thereof, exclusive of sales tax, to which amount shall be added fifteen per cent thereof.

For any machine power tools or equipment which the City Engineer may deem necessary or desirable to use, the contractor shall be allowed a reasonable rental price, to be agreed upon in writing before such work is begun, for each and every hour that said tools or equipment are in use on such work and to which sum no percentage shall be added. Said rental price shall be full compensation also for fuel, lubricants, repairs, transportation and for all other expenses incidental to the use of said tools and equipment, except labor for operation thereof. If a reasonable rental price is not agreed upon before such work is begun, no payment shall be made for such power tools or equipment.

The contractor shall be allowed compensation for payments made to the State Department of Labor and Industries which are occasioned by extra work. These payments shall include Industrial Insurance premiums and fifty per cent of the Medical Aid payments. Compensation for such premiums shall be in the amount of the actual payments made by the contractor to which no percentage will be added.

The compensation as herein provided shall be payment in full for all extra work and shall cover all expenses of every nature, kind and description, including overhead expenses, payments required under the Social Security Act, State Unemployment Compensation Act, Occupational Tax and any other Federal or State revenue acts, together with all premiums on Public Liability and Property Damage Insurance policies, use of small tools and equipment for which no rental is allowed, and profit; provided that a separate payment covering sales tax will be made, in accordance with the State Revenue Act of 1935 and later amendments thereto, on all extra work involving the construction of a facility which does not fall within the meaning of the clause "Publicly owned street, place, road, highway, bridge or trestle which is used or is to be used primarily for foot or vehicular traffic, . . ." as defined in the latest revision of "Rules Relating to the Revenue Act" issued by the Excise Division of the Tax Commission of the State of Washington.

The amount and cost of all work shall be computed by the City Engineer and the amount certified to by him shall be final, conclusive and binding upon the contractor. No claims for extra work under this contract will be allowed unless a memorandum of such work, signed by the contractor and approved by the City Engineer, be furnished the latter as soon as possible, and in any event not later than the twentieth of the month following the performance of such extra work.

54.0 USE OF WATER, LIGHT AND POWER:

The contractor shall not draw water from any hydrant until the required permit has been secured. All water, electric light or power used by the contractor on this work shall be paid for by the contractor at the current rates and the cost of the same shall be included in the contract price for the collection and disposal of garbage, rubbish and certain trade waste.

55.0 LOCAL IMPROVEMENTS:

The Board of Public Works reserves the right to improve any street or alley in such manner as the corporate authorities may direct, which may have the effect for a time of preventing the contractor from traveling his accustomed route or routes for collection. He shall, however, by whatever method he elects, continue to collect the garbage, rubbish and certain trade waste to the same extent as though no interference existed upon the streets or alleys formerly traversed. This shall be done without extra cost to the City of Seattle.

56.0 INDUSTRIAL INSURANCE AND MEDICAL AID:

The contractor shall pay into the City Treasury or to the Department of Labor and Industries of the State of Washington, in cash, the amounts required to be paid to the State of Washington in connection with the Workmen's Compensation Act, or any other payments due the State of Washington in the form of taxes or fees as required by law on account of this contract before payment is made to him by the City on any monthly statement of amount due, and final payment shall not be made until the contractor shall have complied with the provisions of this section.

57.0 DECISIONS OF QUESTIONS:

To prevent all disputes or litigation, it is understood that all questions arising as to the proper performance and the amount of work to be paid for under this contract shall be subject to the decision of the City Engineer, subject to the right of the contractor to appeal to the Board of Public Works, whose decision shall be final.

58.0 DEFAULT OF CONTRACT:

Should the contractor abandon, delay unnecessarily in the performance of, or in any manner refuse or fail to comply with any of the terms of his contract, or neglect or refuse to comply with the instructions of the City Engineer relative thereto, the City Engineer shall notify the contractor in writing of such abandonment, delay, refusal, failure, or neglect and direct him to comply with all provisions of the contract. A copy of such written notice to be mailed to the surety on the performance bond and delivered to the Board of Public Works. The Board of Public Works shall hear the matter at open session within ten days after receipt of such written notice from the City Engineer and shall, not less than five days prior to the date of such hearing, notify the contractor and the surety on the faithful performance bond of the date and place thereof. The contractor agrees to be present at such hearing and show cause why he has abandoned, delayed, refused, failed or neglected to comply with the terms of the contract.

Should the contractor fail to appear or fail to show cause why he has abandoned, delayed, refused, failed or neglected to comply with the terms of the contract, satisfactory to the Board of Public Works, such Board may, with the consent of the City Council by resolution, declare a default of the contract and notify the contractor and the surety on the performance bond of such declaration of default, or the Board of Public Works may take such other action as it may deem advisable.

Upon receipt by the contractor of such declaration of default, the contractor agrees that he will discontinue the work, whereupon the surety on the performance bond may, at its option to be exercised within ten days of such declaration of default, assume the work that the Board of Public Works has ordered discontinued, and proceed to perform the same at its own cost and expense.

Upon such declaration of default, all payments due the contractor shall be retained by the City and applied to the completion of the contract and to damages suffered and expense incurred by the City by reason of such default, unless the surety on the performance bond shall assume the contract, in which event all payments remaining due the contractor at the time of default, less amounts due the City from the contractor and less all sums due the City for damages suffered and expense incurred by reason of such default shall be due and payable to such surety. Thereafter, such surety shall receive monthly payments equal to those that would have been paid the contractor had such contractor continued to perform the contract.

If such surety fails to exercise such option, the Board of Public Works may complete the contract or any part thereof, either by day labor or by re-letting a contract for the same, and the City shall have the right to take possession of and use any or all of the vehicles, materials, equipment, facilities and property of every kind provided by the contractor for the performance of this contract, and to procure other vehicles, equipment and facilities necessary for the completion of the same, and to charge the cost of same to the contractor, together with the cost incident thereto. In such event, however, the contractor shall be entitled to receive reasonable compensation for the City's use of his vehicles, equipment and facilities and reasonable compensation for his material and property so taken.

In the event the Board of Public Works completes the contract at a lesser cost than would have been payable to the contractor under such contract if the same had been fulfilled by said contractor, then the City shall retain such difference. Should such cost to the City be greater, the contractor shall be liable for and pay the amount of such excess to the City.

Should the contractor fail at any time to perform all or any part of the contract for a period of more than 72 hours, for whatever cause or reason, the Board of Public Works may at such time or any time thereafter, with the consent of the City Council, take possession of all the contractor's equipment, vehicles, and facilities, and employ such force as it may deem advisable to continue the work; and the cost of all labor, materials and equipment necessary for such work shall be paid by the City of Seattle out of moneys then due or to become due the contractor under and by virtue of the contract for the work herein specified.

59.0 PAYROLL REPORTS:

The contractor shall keep complete and accurate payrolls, upon which shall appear the following information with respect to each person employed upon or in connection with this contract:

1. Name and residence address;
2. Classification of work;
3. Number of hours employed each day;
4. Total number of hours employed each payroll period;
5. Rate of wages;
6. Total amount earned;
7. All deductions;
8. Net amount paid;
9. Whether a citizen of the United States;
10. Whether a head of a family;
11. Where the contractor's employees are used jointly or part-time on the contract work and part-time on private collection work and the payroll shows the full time of these combination employees, their time shall be segregated as to City contract and private work.

Said payrolls are to be at all times accessible and open to inspection by the Board of Public Works, and copies thereof duly signed by the contractor or his authorized agent, and verified before a Notary Public, are to be filed with the Secretary of said Board not later than seventy-two hours after each payroll period.

All employees shall be paid in full not less often than twice monthly and in lawful money of the United States, in the full amount accrued to each employee at the time of closing of the payroll, which shall not be more than three days prior to the date of payment.

Work performed at the straight time rate shall be shown on one line of the payroll for each day, and any overtime worked or other additional compensation shall be shown on a separate line for each day and extended at the premium rate.

Payroll reports shall be signed by the contractor or his authorized agent.

An authorization for an agent, in substantially the following form, shall be submitted with the first payroll report. If the agent is changed, a new authorization shall be required.

I________________________________, hereby certify that
(Affiant)
______________________________, ________________, pays or
(Agent) (Title)
supervises the paying of the employees of ________________________
(Contractor)
on the following project for the City of Seattle, ________________
______________________________. Ordinance No. __________
(Name of Project)
and is in a position to have full knowledge of the facts set forth in the affidavit respecting the payment of wages of employees working on the project herein mentioned.

____
(Affiant)

Sworn to before me this _____ day of ____________________, 19____.

____
Notary Public in and for the State of
Washington, residing at __________

An affidavit shall accompany each payroll report and shall be in substantially the following form:

I, __________________________, ________________ hereby
(Name of Affiant) (Title)
certify that I pay or supervise the payment of the persons employed by
______________________________ on the following project for the
(Contractor)
City of Seattle, ____
(Name of Project)
Ordinance No. __________.

That the attached payroll sets out accurately and completely the name, occupation, hourly wage rate, total number of hours worked and the full weekly wages earned, of each person employed on the above project for the weekly payroll period from the _____ day of _______________, 19_____, to the _____ day of _____________, 19_____.

That no laborer, workman or mechanic employed on the above project has been paid less than the prevailing rate of wage or less than the minimum rate of wage specified in the contract.

That no rebates have been made either directly or indirectly to or on behalf of said contractor from the full weekly wages earned as set out on the attached payroll and that the full amount due has been paid.

____
(Signature of Affiant)

Sworn to before me this _____ day of _______________________, 19_____.

____
Notary Public in and for the State of
Washington, residing at ____________

The City Comptroller shall withhold payment on all estimates for work performed by the contractor under this contract until all payroll reports of said contractor for work performed have been filed with the Secretary of the Board of Public Works.

60.0 LABOR PREFERENCE:

Preference in employment upon the work contemplated herein or done hereunder shall at all times be given to citizens of the United States who are residents of the City of Seattle, and who shall have been such residents for at least one year last past.

Provided, that citizens of the United States who are not residents of the City of Seattle for at least one year last past may be employed in the event that citizens and residents who are competent and willing to perform the work required under this contract cannot be obtained; that the exclusion of aliens from the work shall also apply to any and all alien members of the undersigned company; and that no alien shall be employed thereon or in connection therewith without a valid and subsisting permit from the Board of Public Works therefor.

To facilitate the enforcement of the above covenants the contractor agrees to prepare and file with the Board of Public Works a complete list containing the names, citizenship status, and resident addresses of all his employees and to keep the same up to date at all times.

61.0 FINAL CLEANUP:

Upon completion of this contract and before final payment is made, the contractor shall remove from the disposal sites and adjoining property, and dispose of all surplus and discarded materials, rubbish, temporary structures, construction equipment and debris which may have accumulated during the life of this contract.

No separate payment shall be allowed for the above work. Payment for the cost thereof shall be included in the bid price.

CONTRACT

THIS CONTRACT, made this 25th day of September, A.D., 1957, by and between the City of Seattle, a municipal corporation of the State of Washington, hereinafter referred to as the "City," and Seattle Disposal Company, hereinafter referred to as the "Contractor":

WITNESSETH:

Section 1. The Contractor agrees, for the consideration hereinafter stated to collect all garbage, rubbish and certain trade waste in the City of Seattle, operate and maintain the various garbage disposal sites and provide earth for cover at the various disposal sites, as provided by Ordinance No. 86373, and in all respects in accordance with the specifications therefor, which are by express reference thereto hereby made a part of this contract and attached hereto.

Section 2. This contract shall take effect on January 1, 1958, and remain in full force and effect for a period of five years, to and including December 31, 1962.

Section 3. The City agrees to pay the contractor the unit price of $2.83 dollars per individual for the calendar year 1958, $2.91 dollars per individual for the calendar year 1959, $3.00 dollars per individual for the calendar year 1960, $3.10 dollars per individual for the calendar year 1961, and $3.20 dollars per individual for the calendar year 1962, for the complete collection of garbage, rubbish and certain trade waste, as specified in the specifications within the corporate limits of the City of Seattle. The annual contract price for each year shall be determined by multiplying the unit price per individual for that year by the population for that year. The population for the first contract year is agreed to be 572,000 and thereafter the population shall be determined as set forth in the specifications, a part hereof.

The City agrees to pay said contractor for the actual quantity of earth delivered and placed as specified in the specifications, a part hereof, the unit price of $0.70 per cubic yard delivered for the calendar year 1958, the sum of $0.75 per cubic yard delivered for the calendar year 1959, the sum of $0.80 per cubic yard delivered for the calendar year 1960, the sum of $0.95 per cubic yard delivered for the calendar year 1961, and the sum of $0.95 per cubic yard delivered for the calendar year 1962.

Section 4. Subject to the provisions of Chapter 63, Laws of Washington for 1945, the said contractor hereby covenants, stipulates and agrees:

That he will pay or cause to be paid to the employees on or in connection with this work or under this contract not less than the current hourly rate of wages specified for the class of labor performed.

That he will not enter directly or indirectly into any agreement with any person or persons for labor or employment at any less wage.

That he will neither make nor permit any assignment or transfer of this contract, or of any of the work to be performed hereunder, nor sublet said work or any part thereof in any manner or by any scheme, device or subterfuge which will permit or secure the performance of labor upon or in connection with this work or under this contract, at a rate of wage less than herein specified.

That every scheme or device by which employees employed upon or in connection with this work or under this contract shall sublet or subcontract the same, or take any transfer or assignment of this contract or of any work herein provided for, as a co-partnership or other association, whereby in lieu of receiving the minimum rate of wages hereinabove specified they shall receive a less sum in cash and become sharers in the profits or losses under this contract in compensation for their labor, shall be deemed a subterfuge, device or scheme to evade the provisions of this contract, and shall be null and void and shall render this contract subject to default.

That the above covenants are made for the benefit of the individual employee of the Contractor, and that any employee performing work or labor under this contract shall have a cause of action against the Contractor for the difference between the wages herein specified and the amount actually paid to such employee.

Section 5. This contract shall not take effect or be in force until the approval of the Contractor's bond by the Mayor and the City Comptroller, and until the same shall be filed with the City Comptroller.

Section 6. In the event of violation of any of these convenants or any provision thereof, payment due from the City of Seattle on any work done under this contract may be withheld until full compliance therewith; and the work may be stopped or, at the discretion of said Board of Public Works, with the consent of the City Council, this contract may be defaulted.

Section 7. The City expressly reserves the right to require the Contractor to make collections at such intervals as the City Engineer shall deem necessary in areas which may hereafter be annexed to the City for a consideration as set forth in the specifications, a part of this contract.

IN WITNESS WHEREOF, said City has caused these presents to be signed by the Chairman of the Board of Public Works and to be attested by the Secretary of said Board; and said Contractor does hereunto set his hand the day and year first above written.

THE CITY OF SEATTLE

By ______________________________
Chairman of Board of Public Works

______________________________(SEAL)
Secretary of Board of Public Works

______________________________(SEAL)

______________________________(SEAL)

______________________________(SEAL)

Appendix D

ST. LOUIS COUNTY, MISSOURI, REFUSE DISPOSAL ORDINANCE

AN ORDINANCE
(No. 308)

To regulate and control the disposal and dumping of garbage, refuse and other trash in that part of St. Louis County outside the incorporated cities; providing penalties for the violation of this ordinance; and repealing St. Louis County Council Ordinance No. 202, 1952, enacted on July 16, 1952, relating to dumps; and declaring an emergency. (As amended by Ordinance No. 337, adopted July 29, 1953.)

BE IT ORDAINED BY THE COUNTY COUNCIL OF ST. LOUIS COUNTY, MISSOURI, AS FOLLOWS:

Section 1. The following Sections shall become a part of the Administrative Code of St. Louis County:

Section 28.01. The County Council of St. Louis County finds, determines and declares that it is necessary and conducive for the protection of the public health, safety and welfare of the people of St. Louis County to provide regulations for the dumping and disposal of garbage, refuse and other trash within St. Louis County. The purpose of this Ordinance is to regulate and control the dumping and disposal of garbage and refuse in those parts of St. Louis County outside the incorporated cities, to the end that the public health, safety and welfare of the people of St. Louis County will be protected and enhanced and to prevent and prohibit the indiscriminate and uncontrolled use of property for dumping purposes in violation of zoning and health regulations and recognized public health standards; to prevent and prohibit open dumping on land in St. Louis County and to require that disposal and dumping of garbage and refuse be authorized and permitted only in County licensed and approved County dumps and sanitary landfills. It is not the purpose of this Ordinance to prohibit any person owning or operating a farm from disposing of garbage from his own household to swine upon said farm, or from collecting and disposing of garbage for the feeding of swine upon said farm, where such disposal shall not violate the health regulations of St. Louis County, and shall be authorized by the laws of the State of Missouri, including House Bill No. 60, as amended, adopted by the Sixty-Seventh General Assembly of Missouri, approved on the 1st day of May, 1953.

Section 28.02. The provisions of this Ordinance shall be in effect in all parts of St. Louis County outside incorporated cities. This Ordinance is enacted pursuant to the St. Louis County Charter and the Constitution of the State of Missouri, which grants to St. Louis County the authority to exercise legislative power on matters pertaining to public health, planning and zoning and police in that part of St. Louis County outside incorporated cities.

Section 28.03. For the purpose of this ordinance certain words and terms are defined as follows:

(a) COUNTY shall mean that portion of St. Louis County outside incorporated cities.
(b) PERSON includes an individual, a corporation or other legal entity, a partnership, and any unincorporated association, and includes the plural.
(c) PRIVATE DUMP shall mean all land or parcels of land on which nonputrescible refuse is accepted for deposit or permitted to be deposited regardless of whether a charge is made therefor.
(d) GARBAGE shall mean all animal and vegetable waste and all putrescible matter.
(e) REFUSE shall mean all waste substances including garbage as well as combustible and noncombustible wastes.
(f) COMBUSTIBLE WASTE shall mean all waste substances capable of incineration or burning, but excluding explosive or highly inflammable material.
(g) NON-COMBUSTIBLE WASTE shall mean all other waste substance not capable of incineration or burning, including ashes, glass, metal, earthenware and the like.
(h) SANITARY LANDFILL shall mean a type of operation in which refuse is deposited by plan on a specified portion of open land, is compacted by force applied by mechanical equipment, and then is covered by a layer of earth, ashes or suitable covering material to a depth of at least two (2) feet.
(i) ENFORCEMENT OFFICER shall mean the Health Commissioner of St. Louis County.

Section 28.04. It shall be unlawful for any person, firm, association, or corporation, or any combination or combinations of the same, to use any land, premises or property within the County for the dumping or disposal of any garbage, refuse or other waste materials of any kind, without first making application for and securing a license so to do. The issuance of such license shall be subject to and governed by the following provisions:

(1) The application for a license to operate a private dump or sanitary landfill shall be filed with the Health Commissioner and shall contain a description and plat of the land on which the disposal of refuse is proposed, a description of the sequence and plan of operation, availability of and equipment for water supply, type and capacity of equipment to be used for operations, plans for fire, nuisance and vermin control, existing and proposed roadways and easements, existing topography and water courses, together with a diagram and written statement explaining the proposed location and extent of earthwork and fill operations, proposed equipment and estimated daily or weekly volume of garbage and refuse, facts which show that public convenience and necessity and the public health and general welfare of the people of the County require the granting of a license to the applicant, and such other information as may be required by the Council. Copies of the application shall be forwarded by the Health Commissioner to the Planning Commission for its study and recommendation.

The Health Commissioner shall examine the premises to determine whether public convenience and necessity require the granting of the permit to the applicant and whether the granting of the permit to the applicant is to the best interest of St. Louis County and whether the granting of the permit to the applicant would or would not violate the health regulations of St. Louis County or would, in any way, create a hazard or menace to the public health or would, in any way, create a nuisance to the people of St. Louis County, and shall make a report giving his recommendations to the County Council and shall submit a copy of his report to the Planning Commission.

The Planning Commission shall make a report to the County Council as to whether or not the granting of the permit in the location described in the application would be a violation of the zoning regulations of St. Louis County and shall submit a copy of this report to the Health Commissioner. The Planning Commission shall also report to the County Council as to the effect of such proposed use upon the character of the neighborhood, the traffic conditions, public utility facilities and other matters pertaining to the general welfare, and shall advise the County Council as to whether public convenience and necessity require the granting of a permit to the applicant.

In determining whether public convenience and necessity require the issuance of a permit to the applicant, both the Health Commissioner and the Planning Commission shall consider such matters as:

(1) The number of dumps and sanitary landfills necessary for the entire County.
(2) The locations best suited to serve the entire County.
(3) The length of time that a proposed location can be expected to be used as a dump or sanitary landfill for the best interests of the people of St. Louis County.
(4) The possible effect on the area in the vicinity of the proposed dump or sanitary landfill.

The report to the County Council by the Planning Commission shall be made in accordance with the provision of Section 7 of Article XVII of the zoning ordinance in St. Louis County.

Before submitting their reports to the County Council, the Planning Commission and the Health Commissioner shall notify in writing all persons heretofore licensed under this ordinance and, if requested in writing by any such person within seven days from the date of the mailing of the notice to the last known address of the licensee or licensees, shall hold a joint public hearing on the question of whether public convenience and necessity and the public health and general welfare of the people of St. Louis County require the issuance of a permit to the applicant. The entire proceeding and testimony offered at such joint public hearing shall be transcribed by a reporter and the transcription thereof shall be transmitted to the County Council.

Thereafter, the Health Commissioner and the Planning Commission shall submit their reports and recommendations to the County Council, including the above-mentioned transcript, stating their reasons why they recommend that the application be granted or denied and shall send a copy thereof to the applicant and to any person who has requested in writing a hearing on the application as hereinabove set forth. The County Council shall then consider the reports and recommendations so transmitted by the Health Commissioner and the Planning Commission and if the County Council finds that public convenience and necessity, as well as the public health and general welfare of the people of St. Louis County, require, shall issue a permit to the applicant; otherwise, the application for a permit shall be denied and the St. Louis County Clerk shall be instructed to notify the applicant. Such permit shall be issued by the County Council upon the payment of annual fee of Two Hundred Dollars ($200.00) payable to the Treasurer of St. Louis County, and to be deposited by him in the Health Center Maintenance Fund, and upon delivery to St. Louis County of a cash or corporate bond in the amount of $1,000.00; said cash or corporate bond shall run to St. Louis County, Missouri, and shall be conditioned as follows:

a) That the permittee, his agents and servants, will comply with all of the terms, conditions, provisions, requirements and specifications contained in this Ordinance.
b) That the permittee, his agents and servants, will faithfully operate the dump or landfill for which the permit is issued in accordance with the provisions of this Ordinance.
c) That the permittee, his agents and servants, will save harmless St. Louis County from any expense incurred through the failure of the permittee, his agents and servants, to operate and maintain the dump or landfill as required by this Ordinance including any expense the County may be put to for correcting any condition or violation of this Ordinance by the County's own labor and equipment, whenever the Health Commissioner determines it is necessary for the County to correct any unhealthy condition or conditions violative of this Ordinance or from any damages growing out of the negligence of the permittee or his agents or servants.
d) Before acceptance all bonds shall be approved by the County Council. If a corporate bond is offered, it shall be executed by a surety or guaranty company qualified to transact business in the State of Missouri. If a cash bond is offered, it shall be deposited with the St. Louis County Clerk, who shall give his official receipt therefor, reciting that said cash has been deposited in compliance with and subject to the provisions of this Ordinance.

Section 28.05. No person shall permit the disposing of any refuse in any quarry in St. Louis County unless the same is operated as a licensed dump or sanitary landfill in accordance with this Ordinance. Quarries operated as dumps may accept for deposit only non-combustible refuse having no putrescible material therein, and the dumping of garbage and combustible refuse in quarries is hereby prohibited, unless said quarries apply for and receive a permit to operate a sanitary landfill.

Section 28.06. The dumping of garbage and combustible material on private dumps is prohibited unless operated as a sanitary landfill in accordance with this Ordinance.

Section 28.07. The following regulations shall be observed by any person, firm or corporation to whom a permit is issued by the St. Louis County Council for the operation of a sanitary landfill. These regulations shall govern the operation of all St. Louis County approved sanitary landfills, and any failure to observe these regulations shall be sufficient grounds for the revocation of the permit by the Council.

(A) All garbage and other refuse accepted by the permit holder shall be thoroughly compacted by equipment of a size and weight capable of producing a downward or ground pressure of at least _____ pounds[1] per square inch. Such equipment shall have sufficient weight and capacity to carry out all necessary operations to the satisfaction of the enforcement officer. Sufficient auxiliary equipment shall be maintained on the site or otherwise available to permit operation in case of a breakdown.

(B) Mixed refuse material shall be spread out on the working face of the landfill so that the depth does not exceed a maximum depth of two (2) feet prior to its compaction.

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[1] Five pounds are recommended by the American Public Works Association's Committee on Refuse Disposal.

(C) The areas shall be continually policed to prevent fire and the blowing of papers; shall be neat and sanitary at all times, and shall be covered at the end of each day's operation, as well as when wind conditions warrant it through the day, with sufficient material to prevent blowing papers and unsightly conditions. The size of the active face on which refuse is being currently deposited shall be kept to a minimum.

(D) Cover material will consist of earth, loam, clay, sand, etc., or a mixture of at least 50 percent earth and other inert materials, such as ashes, cinders or gravel. A minimum depth of 12 inches of compacted cover and final spread cover material shall be kept on all inactive faces of the landfill at all times. The active faces of the landfills should be covered at the end of each day's operation, or as otherwise directed by the Health Commissioner, with at least 6 inches (before compaction) of cover material.

(E) When the fill has been brought up to two (2) feet below the desired finished grade, it shall be covered with at least ____ inches[2] of compacted cover material graded and seeded in such a manner as to prevent erosion.

(F) Where the "trench system" of sanitary landfill is used, successive parallel trenches must be at least two (2) feet apart.

(G) All garbage and refuse material existing on the site at the time the permit is issued either in the form of an open dump or any other form, shall be collected, compacted, and covered with cover material at least one (1) foot in depth if below the desired finished grade, or with inert material at least two (2) feet in depth at the finished grade. This cover operation shall be completed within fifteen (15) working days after the issuance of a special permit for the sanitary landfill.

(H) The premittee or operator shall erect such temporary or permanent fences or take other measures as may be necessary to reasonably control blowing of paper and other materials from the landfill.

(I) Any materials salvaged from the fill must be handled and stored in such a manner as to prevent rat harborage and permit proper operation of the landfill. Such salvaged material must be removed to a location at least two-hundred (200) feet from the working surface so as not to interfere with the compacting and covering. All salvaged material must be completely removed from the landfill site every twenty-four (24) hours unless provision is made for temporary storage within an enclosed, roofed and rat-proof structure approved by the Enforcement Officer.

(J) Burning of any materials deposited in a dump or landfill is expressly prohibited, except that when the dump or landfill is located in a "J" or "K" Industrial District. In the latter districts tree limbs, wooden crates, or similar combustible material, which will burn readily without smouldering or producing offensive odors, may be burned in a separate place at least two hundred (200) feet away from the area where refuse is being compacted and covered, provided precautions are taken to confine the fire, and the burning is done in such a manner as not to create a nuisance condition. All burning shall be restricted to the hours between 8:00 A.M. and 12:00 Noon.

(K) Adequate fire-fighting equipment shall be available at all times on the site or the operator of the landfill shall furnish the Enforcement Officer with proof of a fire-fighting agreement between the operator and the local fire district.

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[2] At least 24 inches are required under Section 28.03 (h) and are recommended by the American Public Works Association's Committee on Refuse Disposal.

(L) No fill shall be placed in streambeds or other areas where streams would be obstructed or where erosion by the stream would remove cover material. There shall be no seepage or drainage of any material from the fill of such a nature as would constitute an odor nuisance, or health hazard, or pollute any water course.

(M) The permit holder shall provide an access road, approved by the Enforcement Officer, that is passable in all types of weather conditions to the dumping site.

(N) The license holder shall also provide an auxiliary fill site available and ready for use during periods of heavy rain or snowfall, and when the area being filled and covered may not be reached because of said weather conditions. The permit holder shall also take precautions to eliminate excess dust in dry weather.

(O) Insects and rodents on the landfill site shall be controlled and exterminated as directed by the Enforcement Officer.

(P) For good and sufficient reasons the Enforcement Officer may grant exceptions to the above operating procedures and standards or may impose additional requirements subject to specific site conditions. The Enforcement Officer shall advise the County Council of the exceptions or additional requirements granted at the next regular council meeting after the exceptions or additional requirements are granted.

Section 28.08. No person, including those persons hauling or disposing of garbage or refuse, trash or other rubbish for a fee, shall deposit or dispose of any garbage, trash or other refuse on any property in St. Louis County not operated under a permit issued by the St. Louis County Council. Each sanitary landfill shall display a prominent sign containing the word "Approved Sanitary Landfill operated under Permit No.__________ issued by the St. Louis County Council;" provided, however, that nothing in this Ordinance shall be deemed to prohibit or prevent the owner or operator of a farm engaged in the raising and feeding of swine from disposing of garbage for the feeding of his own swine so long as such disposal shall not constitute a nuisance nor a health hazard to the people of St. Louis County or be contrary to the Health Regulations of St. Louis County, and subject to the laws of the State of Missouri, including House Bill No. 60, as amended, adopted by the Sixty-Seventh General Assembly of Missouri, and approved on the 1st day of May, 1953.

Section 28.09. The officer responsible for the enforcement of the provisions of this ordinance shall be the Health Commissioner. He shall provide adequate and frequent inspections of the sanitary landfill sites and to this end shall be authorized to call upon the Planning Commission for assistance in making inspections. He shall notify any permit holder who is violating the provisions of this Ordinance of the specific manner in which the Ordinance is being violated. Unless said violation is corrected within twenty-four (24) hours after notice in writing to the permit holder by the Enforcement Officer, the Enforcement Officer shall notify the County Council of any violation of the provisions of this Ordinance and the County Council may, after a public hearing to which the violator shall have been invited, suspend or revoke any permit for non-compliance or violation of any of the provisions of this Ordinance or when satisfied that the landfill constitutes a real menace and nuisance to the health, safety and welfare of the immediate residents in the neighborhood in which it is located. In the event the permit holder refuses to correct the violation within twenty-four (24) hours after notice in writing by the Enforcement Officer, the Enforcement Officer may, if he deems it necessary in the interest of public health, enter upon the premises of the dump or landfill and, either with the equipment and employees of the license holder, or with County owned or leased equipment and County employees, do such work as is necessary to correct any condition violative of this Ordinance, and which in his opinion if left uncorrected may be hazardous to the public health. The cost to the County of correcting such conditions in privately owned dumps or landfills shall be assessed against the permit holder who shall be required to pay all costs and expenses of the County in correcting said conditions.

Section 28.10. Any permit or license granted hereunder may be revoked or suspended at any time for any failure to pay the license fee or the cost of correcting hazardous conditions, as hereinbefore set forth, or whenever in the opinion of the Health Commissioner the continuance of the landfill or other means of final disposal of refuse would endanger the health, welfare or safety of the public; provided that no such permit or license shall be revoked or suspended except for failure to pay the fee, or the cost of correcting hazardous conditions as herein provided except after public hearing before the St. Louis County Council after the notice of said hearing and the purpose thereof shall have been sent to the permit holder at least ten (10) days prior to the date of said hearing, at which hearing any person interested in said landfill shall have the right to be heard.

Section 28.11. St. Louis County Council Ordinance No. 202, 1952 enacted on the 16th day of July, 1952, relating to dumps, is hereby repealed, and all Ordinances or parts of Ordinances in conflict herewith are to the extent of such conflict hereby repealed. Any person who violates or causes to be violated any provisions of this Ordinance, shall upon conviction thereof, be fined not less than Twenty-five ($25.00) Dollars nor more than Five Hundred ($500.00) Dollars and each day of such violation shall constitute a separate offense.

Section 28.12. The passage of this ordinance being deemed necessary for the immediate preservation of the public health, safety and welfare of the people of St. Louis County, an emergency is hereby declared to exist and this Ordinance shall be in full force and effect immediately upon its passage, and approval by the County Supervisor.

ADOPTED THIS 24TH DAY OF JUNE, 1953

Frank L. Martini
ACTING CHAIRMAN, COUNTY COUNCIL

APPROVED THIS 24TH DAY OF JUNE, 1953

Luman F. Matthews
COUNTY SUPERVISOR

ATTEST:

Leo E. Sievers
COUNTY CLERK

Appendix E

INCINERATOR INSTITUTE OF AMERICA 1958 STANDARDS FOR DESIGN OF HOME INCINERATORS AND CLASSIFICATION BY TYPES OF REFUSE BURNED[1]

FOREWORD

The Incinerator Standards stated herein have been compiled by the Incinerator Institute of America, a non-profit organization. Considerable study has gone into this preparation in full realization that such a study might result in a set of standards influenced by a compromised viewpoint of the interested manufacturers.

A further test of the soundness of these results was made by the Institute through the retention of an outside qualified organization. The Research Division of New York University, College of Engineering, was authorized to study the problems of the industry, its aims, and the proposed Standards. This set of Standards has been developed after consideration of the recommendations made under this research project.

In the realization that there are literally thousands of communities which do not have a Code, and hundreds of communities that have Codes only in part, we trust this will be accepted as a Standard, or perhaps as a definite Code.

To those city officials who wish to have assurance that the equipment being installed in their areas complies with the principles set forth in these Standards, the members of the Incinerator Institute of America pledge to use a Standards Plate only on such equipment that complies.

The members of the Institute feel that only by the publication of this information and its acceptance by interested officials can the products of the industry be improved and upgraded to conform to the modern requirements of air pollution control and safety authorities.

We have purposely refrained from referring to the design construction of stacks and chimneys, as this phase is covered by the National Board of Fire Underwriters in their pamphlet No. 82.

The Incinerator Institute of America has a standing committee whose purpose is the review and improvement of these Standards. The Institute will welcome your comments as to further improvement.

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I.I.A. INCINERATOR STANDARDS

1. Definitions

1.1 *Incinerator Terminology*

INCINERATOR

Combustion apparatus in which solid, semi-solid, or gaseous combustible wastes are ignited and burned to carbon dioxide and water vapor, and from which the solid residues contain little or no combustible material.

PRIMARY COMBUSTION CHAMBER

Chamber within an incinerator where primary ignition and burning of the waste occur.

SECONDARY COMBUSTION CHAMBER

Chamber connected with the primary chamber where unburned combustible materials from the primary chamber are completely burned.

DROP ARCH

Any refractory construction in the primary or secondary chamber that serves to deflect the products of combustion.

BRIDGE WALL

A partition wall between the primary and secondary chambers over which pass the products of combustion.

CURTAIN WALL

A refractory construction or baffle, which serves to deflect gases from the primary combustion chamber in a downward direction.

BAFFLE

Any refractory construction intended to change the direction of flow of the products of combustion.

CHECKER WORK

Multiple openings in a bridge wall, drop arch, or other walls through which the products of combustion pass. The primary purpose is to promote turbulent mixing of the gases.

GRATE

Surface with suitable openings, to support the fuel bed and permit passage of air through the burning fuel. It is usually located in the primary combustion chamber, and is designed to permit removal of unburned residue, and may be horizontal or inclined and stationary or movable.

COLD DRYING HEARTH

A surface within the primary chamber upon which wet waste material is deposited for drying, prior to burning.

HOT DRYING HEARTH

A surface upon which wet material is placed to dry by the action of hot combustion gases that pass successively over the wet material and under the hearth.

AUXILIARY-FUEL FIRING EQUIPMENT

Equipment to supply additional heat, by the combustion of an auxiliary fuel, for the purpose of attaining temperatures sufficiently high (a) to dry and ignite the waste material, (b) to maintain ignition thereof, and (c) to promote complete combustion of combustible solids, vapors, and gases.

COMBUSTION AIR

(a) Primary: Air that passes through the fuel bed.

(b) Secondary: Any air, controlled with respect to quantity and direction, supplied beyond the fuel bed, as through ports in the walls or bridge wall of the primary combustion chamber (overfire air) or the secondary combustion chamber, for the purpose of completing combustion of combustible materials in the gases from the fuel bed.

DRAFT

The pressure difference between incinerator, or any component part, and the atmosphere, which causes the products of combustion to flow from the incinerator to the atmosphere.

(a) Natural Draft: The pressure difference due to the temperature difference between the flue gases and the atmosphere.

(b) Induced Draft: The pressure difference created by the action of a fan, blower, or ejector, which is located between the incinerator and the stack, or at the stack exit.

(c) Forced Draft: The pressure difference created by the action of a fan, blower, or ejector, which supplies the primary combustion air above atmospheric pressure.

DAMPER

A manually or automatically controlled device used to regulate the rate of flow of air or other gases.

BREECHING

A passage for conducting the products of combustion to the stack or chimney.

BREECHING BY-PASS

An arrangement of breeching and dampers to permit the intermittent use of two or more passages for products of combustion to the stack or chimney.

FLY ASH

Suspended particulate matter in products of combustion.

FLY ASH COLLECTOR

A device designed to remove fly ash from products of combustion by electrical or mechanical means.

FLUE GAS WASHER OR SCRUBBER

Equipment designed to remove fly ash, odorous compounds, and other objectionable materials from products of combustion, by means of sprays, wet baffles, or similar devices.

SETTLING CHAMBER

Chamber designed to reduce velocity of gases sufficiently to promote the settling of fly ash. May be integral part of secondary combustion chamber.

STACK OR CHIMNEY

A vertical passage for conducting products of combustion to the atmosphere.

SPARK ARRESTER

A screen to prevent sparks, embers, or other ignited material above a given size from being expelled to the atmosphere.

2. Waste Analysis

2.1 The basis for satisfactory incinerator operation is the proper analysis of the waste to be destroyed, and the selection of proper equipment to best destroy that particular waste. As a matter of convenience, all types of waste to be destroyed have been classified as follows:

TYPE 1 WASTE

Rubbish, consisting of combustible waste such as paper, cartons, rags, wood scraps, sawdust, foliage, and floor sweepings from domestic, commercial, and industrial activities.

This type of waste may contain up to 25% moisture, up to 10% incombustible solids, and have a heating value of 6500 B.T.U. per pound as fired.

TYPE 2 WASTE

Refuse, consisting of an approximately even mixture of rubbish and garbage by weight. This type of waste is common to apartment and residential occupancy, consisting of up to 50% moisture, 7% incombustible solids, and 4500 B.T.U. per pound as fired.

TYPE 3 WASTE

Garbage, consisting of animal and vegetable wastes from restaurants, cafeterias, hotels, hospitals, markets, and like installations.

This type of waste may contain up to 70% moisture, up to 5% incombustible solids, and have a heating value of 2500 B.T.U. per pound as fired.

TYPE 4 WASTE

Human and animal remains, consisting of carcasses, organs and solid organic wastes from hospitals, laboratories, abattoirs, animal pounds, and similar sources, consisting of up to 90% moisture, 5% incombustible solids, and having a heating value of 1000 B.T.U. per pound as fired.

TYPE 5 WASTE

By-product waste, gaseous, liquid or semi-liquid, such as tar, paints, solvents, sludge, fumes, etc., from industrial operations. B.T.U. values must be set on individual materials to be destroyed.

TYPE 6 WASTE

Solid by-product waste, such as rubber, plastics, woodwaste, etc., from industrial operations. B.T.U. values must be set on individual materials to be destroyed.

3. Classification of Incinerators

CLASS I

Portable, packaged, completely assembled, direct fed, having not over 5 cu. ft. storage capacity, or 25 lbs. per hour burning rate, suitable for Type 1 or Type 2 waste.

CLASS IA

Portable, packaged, or job assembled, direct fed, over 5 cu. ft. to 15 cu. ft. storage capacity, or 25 lbs. per hour to 100 lbs. per hour burning rate in primary combustion chamber, suitable for Type 1 or Type 2 waste.

CLASS II

Flue fed incinerators, over 2 sq. ft. (burning area) capacity, suitable for Type 1 or Type 2 waste.

CLASS III

Direct fed incinerators with storage capacity of 15 cu. ft. and over, or a burning rate of 100 lbs. per hour and over, normally suitable for Type 1 or Type 2 waste.

CLASS IV

Direct fed, type normally suitable for Type 3 waste, over 75 lbs. per hour.

CLASS V

Municipal incinerators.

CLASS VI

Crematory, and pathological units, normal destruction of Type 4 waste. Same as Class III and shall have hot refractory hearth over the total burning area.

CLASS VII

Retort type equipment designed for specific by-product waste, Type 5 or Type 6. Same as Class II except that waste to be Type 5 or Type 6. Type 6 waste to be burned on hot or cold refractory hearth or crucible.

4. Specifications of Incinerators by Classes

4.1 Class I

4.1.1—This Class suitable for Type 1 or Type 2 waste.

4.1.1.1—Where Type 2 waste is to be incinerated, the incinerator shall be equipped with an auxiliary burner.

4.1.2—These incinerators shall have a sufficient thickness of refractory lining or insulation to prevent excessive and destructive heating to adjacent materials of construction which are not a part of the incinerator, and provisions are to be made for expansions to reduce or eliminate injury to outer or basement walls.

4.1.3—These incinerators shall be so designed that when operated according to the manufacturers' instructions they shall not emit fly ash in excess of .85 lbs. per 1,000 lbs. of flue gas, corrected to 12% CO^2, nor shall they produce smoke in excess of Ringlemann No. 2 for more than five minutes in any hour.

4.1.4—They should be constructed to withstand intermittent internal temperatures as high as 1800° F. without cracking, warping, or other failure of structural parts in such manner as to permit flame passage or emission of combustion gases or sparks to the exterior. The design shall be such that when installed in accordance with the manufacturers' directions and specified clearances, the continued operation of the unit at maximum burning rate of shredded newspaper for a period of at least one hour will not raise the temperature of surrounding combustible walls, floors, or ceilings more than 90° F. above normal room temperature.

4.2 Class IA

4.2.1—This Class suitable for Type 1 or Type 2 waste.

4.2.1.1—Where Type 2 waste is to be incinerated, the incinerator shall be equipped with an auxiliary burner.

4.2.2—These incinerators shall be so designed that when operated according to the manufacturers' instructions they shall not emit fly ash in excess of .85 lbs. per 1,000 lbs. of flue gas, corrected to 12% CO^2, nor shall they produce smoke in excess of Ringlemann No. 2 for more than five minutes in any hour.

4.2.3—They should be constructed to withstand intermittent internal temperatures as high as 1800° F. without cracking, warping, or other failure of structural parts in such manner as to permit flame passage or emission of combustion gases or sparks to the exterior. The design shall be such that when installed in accordance with the manufacturers' directions and specified clearances, the continued operation of the unit at maximum burning rate of shredded newspaper for a period of at least one hour will not raise the temperature of surrounding combustible walls, floors, or ceilings more than 90° F. above normal room temperature.

4.3 Class II

4.3.1—This Class suitable for Type 1 or Type 2 waste.

4.3.1.1—These incinerators shall be served by a separate flue to which the incinerator only will be connected.

4.3.2—Flue-feed door openings shall be so selected that the clear opening of the door does not exceed one-third (⅓) of the cross-sectional area of the flue—this to minimize the chances of clogging by large parcels. Such doors shall be self-closing.

4.3.3—All flue fed incinerators shall be provided with the following:

(a) In the primary combustion chamber an auxiliary burner, either manual or automatic, equipped with a pilot and flame failure protection device.

(b) A roof settling chamber proportioned to reduce gas velocity to ¼ the velocity of flue gases, so that fly ash will be reduced to allowable limits.

4.3.4—Chimney height above roof shall be five feet above the highest point of the building, or above any obstruction within 50 feet, to protect it against possible interference.

4.3.5—Flue fed incinerators shall have a minimum firebrick lining of 4½ inches in the furnace chamber to assure ample fire protection at operating temperatures. The flue serving the unit shall have a refractory lining with

Table E-1

BROAD CLASSIFICATION OF WASTES TO BE INCINERATED

Type of Waste Class Description	*Principal Components*	*Approximate Composition % by Weight*	*Moisture Content %*	*B.T.U./lb. as Fired*	*Min. B.T.U./hr. Aux. Fuel Required per lb. Waste*	*Incombustible Solids %*
*1 Rubbish	Combustible waste, paper, cartons, rags, wood scraps, floor sweepings; domestic, commercial, industrial, sources.	Rubbish	25%	6500	0	10%
*2 Refuse	Rubbish and garbage; residential sources	Rubbish 50% Garbage 50%	50%	4500	1500	7%
*3 Garbage	Animal and vegetable wastes; restaurants, hotels, markets, institutional, commercial, and club sources	Swill Rubbish	70%	2500	4000	5%
4 Animal solids and organic wastes	Carcasses, organs, solid organic wastes; hospital, laboratory, abattoirs, animal pounds, and similar sources	Organic solids	90%	1000	8000	5%
5 Gaseous, liquid or semi-liquid process wastes	Combustibles requiring pressure atomizing burner equipment	Liquid	Dependent on predominant components	Variable according to wastes survey	Variable according to wastes survey	Variable according to wastes survey
6 Semi-solid and solid process wastes	Combustibles requiring hearth, retort, or grate burning equipment	Organic solids Inorganic solids	Dependent on predominant components	Variable according to wastes survey	Variable according to wastes survey	Variable according to wastes survey

*The above figures on moisture content, ash, and B.T.U. as fired have been determined by analysis of many samples. They are recommended for use in computing heat release, burning rate, velocity, and other details of incinerator designs. Any design based on these calculations can accommodate minor variations.

a minimum thickness of 2½ inches for a height of 15 feet above the roof of the combustion chamber where the burning area does not exceed 9 sq. ft.; and shall have a lining with a minimum thickness of 4½ inches for a height of 30 feet above the combustion chamber roof when the burning area exceeds 9 sq. ft.

4.3.6—For this class of incinerator the minimum grate area shall be 0.15 sq. ft. per sleeping room.

4.3.7—The primary chamber in this class of incinerator shall have a minimum volume of 3 cu. ft. for each sq. ft. of grate area.

4.3.8—Secondary or over-fire air shall be provided through adjustable openings equivalent in area to 2 sq. inches per sq. ft. of grate area.

4.3.9—Roofs of all incinerators under this heading shall be so designed that no metal supports or lintels shall be directly exposed to the heat.

4.4 Class III

4.4.1—This Class incinerator suitable for Type 1 or Type 2 waste.

4.4.1.1—When designed to burn Type 1 waste shall contain cast iron grates, stationary or dump or combination thereof, with air openings not less than 40% of total burning area.

4.4.1.2—When designed to burn Type 2 waste it shall contain combination drying hearth and cast iron grate area, each approximately 50% of the total burning area. Where step grates are used in lieu of hearth, they shall provide at least 50% of the grate surface.

4.4.2—Maximum burning rate per sq. ft. of primary area shall be as shown in Table E-2.

Table E-2

MAXIMUM BURNING RATE LBS./SQ. FT./HR. OF VARIOUS TYPE WASTES

Capacity Lbs./Hr.	*Logarithm*	*#1 Waste*	*#2 Waste*	*#3 Waste*
		Factor 13	*Factor 10*	*Factor 8*
100	2.00	26#	20#	16#
200	2.30	30#	23#	18#
300	2.48	32#	25#	20#
400	2.60	34#	26#	21#
500	2.70	35#	27#	22#
600	2.78	36#	28#	22#
700	2.85	37#	28#	23#
800	2.90	38#	29#	23#
900	2.95	38#	30#	24#
1000	3.00	39#	30#	24#

Above figures calculated as follows:

Maximum burning rate lbs. per sq. ft. per hr. for types #1, #2, #3 wastes using factors as noted in the formula.

B_R = factor for type waste × log of capacity/hr.
#1 waste factor 13
#2 waste factor 10
#3 waste factor 8
B_R = max. burning rate lbs./sq. ft./hr.
I. E., assume incinerator capacity of 100#/hr. for type #1 waste.
B_R = 13 (factor for #1 waste) × log 100 (capacity/hr.)
13 × 2 — 26#/sq. ft./hr.

4.4.3—When burning Type 2 waste, gas or oil burners are to be provided to supply at least 1500 B.T.U. per pound of waste at rated capacity. Gas burners to be provided with flame failure protection equipment.

4.4.4—All incinerators of this class shall be of heavy duty construction, and shall include primary and secondary combustion chambers. Total heat release in entire incinerator, excluding ash pit, shall be not more than 40,000 B.T.U. per cu. ft. per hour. Secondary combustion chamber shall be designed so that gas velocity at some point in the secondary chamber shall not exceed 9 feet per second (at 1400° F.). The length of travel at 9 feet per second shall be a distance not less than the square root of the cross section of the passage which achieves that velocity. For purposes of calculating gas velocities, air for combustion shall be figured at 15 lbs. per 10,000 B.T.U. waste. This includes 100% excess air. Temperature of flue gases shall be calculated at not less than 1400° F.

4.4.5—Secondary or over-fire air shall be provided through adjustable openings which shall be not less than 2 sq. inches per sq. ft. grate area at minimum opening.

4.4.6—Material charging may be direct, side, end, or top, but top charge chutes shall not be longer than one-half (½) the height of the incinerator. Refractory linings laid in fireclay or high temperature cement, not less than 4½ inches thick up to 500 lbs. per hour, and 9 inches thick over 500 lbs. per hour. Exterior walls 8 inches common masonry with minimum 1 inch air space between lining and exterior walls, or in lieu of masonry, a steel case with 4½ inches insulating firebrick or its equivalent insulation. All Class III incinerators shall have exterior structural steel framework, designed to withstand interior thrusts and support door and appurtenant assemblies.

4.4.7—All types of waste shall be burned without producing smoke in greater density than Ringlemann No. 2 for more than 5 minutes in any hour, and shall not emit fly ash to exceed .85 lbs. per 1,000 lbs. of flue gas, corrected to 12% CO^2. Units up to maximum of 24 sq. ft. total burning area may be manually operated and controlled, provided the user has an operator in attendance a sufficient time during operation to guarantee functioning within code limits or, in lieu of such an operator, a dust collector shall be provided. Over 24 sq. ft. total burning area a dust collector is required.

4.4.8—Where no flue gas temperature reduction is effected, breechings must be of high temperature construction with steel exterior, lined with firebrick, and a guillotine or sliding damper. A barometric damper shall also be provided in a size not less than three-fourths (¾) the area of the breeching or stack in which it is located.

4.4.9—If flue gas temperature is reduced below 750° F. an unlined breeching and vent may be used.

4.5 Class IV

4.5.1—Construction and design to be the same as Class III except as follows:

4.5.1.1—This Class normally to burn Type 3 waste on hot drying hearth with cast iron grate area not to exceed 35% of total burning area. Where step grates are used in lieu of hearth, they shall comprise at least 65% of the grate area surface.

4.5.1.2—Gas or oil burners are to be provided to supply at least 4000 B.T.U. per pound of waste at rated capacity. Gas burners to be provided with flame failure protection equipment.

4.6 Class V

4.6.1—Construction of this Class of equipment is subject to special design formulae.

4.7 Class VI

4.7.1—Design and construction shall be the same as Class III, except that unit shall have hot refractory hearth over total burning area and shall have burners in primary and secondary chambers. Primary burners shall supply at least 8000 B.T.U. per lb. of waste at rated capacity. Secondary burner shall supply at least 4000 B.T.U. per lb. of waste at rated capacity. Gas burners to be provided with flame failure protection equipment.

4.8 Class VII

4.8.1—This Class shall be the same as Class III except that heat release, burning rate, and velocities shall be determined from an analysis of waste to be incinerated in each instance.

5. General

5.1 A name plate shall be conspicuously fastened to the incinerator indicating the manufacturer's name, model number, and rated capacity of the unit; also indicating the type of waste for which it is designed.

Appendix F

NATIONAL BOARD OF FIRE UNDERWRITERS 1958 STANDARDS FOR INSTALLATION OF DOMESTIC INCINERATORS AS RECOMMENDED BY THE NATIONAL FIRE PROTECTION ASSOCIATION[1]

Definitions

The word "approved" as used in this standard means acceptable to the authority having jurisdiction. For insurance purposes the authority referred to is the insurance inspection bureau, department or organization having jurisdiction.

The word "shall" indicates provisions which are considered essential for protection of life and property.

The word "should" indicates advisory provisions.

The authority having jurisdiction should be consulted on any questions arising in the application of these standards.

Underwriters' Laboratories, Inc., tests devices and materials for compliance with the standards of construction and performance established by the Laboratories with regard to their suitability for installation in accordance with the appropriate standards of the National Board of Fire Underwriters. Such devices and materials are listed in the following Laboratories' publications:

Fire Protection Equipment List
Gas and Oil Equipment List
Electrical Appliance and Utilization Equipment List
Electrical Construction Materials List
Hazardous Location, Equipment List
Accident, Automotive, and Burglary Protection Equipment Lists
Bi-Monthly Supplement to All Lists

Copies may be obtained from inspection departments or from Underwriters' Laboratories, Inc., Chicago, New York or Santa Clara, Calif.

Incinerators

No. 82—May 1958

This edition of the Standard on Incinerators was adopted by the National Fire Protection Association on May 23, 1958, on recommendation of the Committee on Chimneys and Heating Equipment. It is a complete revision of the last edition dated 1955.

This standard was first adopted by the NFPA in 1948 on recommendation of the Committee on Field Practice. In 1953 a completely revised edition of the text on incinerators was prepared by a representative subcommittee and adopted by the NFPA on recommendation of the Committee on Building Construction. The subject of incinerators was turned over to the Committee on Chimneys and Heating Equipment in 1956. Revised editions were adopted in 1955 and 1958. The original 1948 text covered both rubbish handling and incinerators; the 1953, 1955 and 1958 revisions covered only incinerators. In the present printing incinerators and rubbish handling are treated as separate standards, Nos. 82 and 82A, respectively, No. 82A on Rubbish Handling being unchanged from the 1948 edition.

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[1] NBFU Pamphlet No. 82, reproduced with permission.

Standard No. 82 on Incinerators is in three parts as follows:

Part I —Domestic Type Incinerators
Part II —Flue-Fed Incinerators (Apartment House Type)
Part III—Commercial and Industrial Type Incinerators

Previous editions of this standard have also been adopted and published by the National Board of Fire Underwriters as NBFU No. 82.

. . . .

Standard for Incinerators

PART I

DOMESTIC TYPE INCINERATORS

1.1 *Application.*

The provisions of this Part apply to direct-fed incinerators, including types as defined in 1.2 below, designed primarily for use in one and two family dwellings for the burning of ordinary combustible waste materials and garbage incidental to domestic occupancy and having a firebox or charging compartment of not over 5 cubic feet in capacity. Section 1.12 applies to small outdoor waste burners. For flue-fed incinerators see Part II and for larger direct-fed incinerators see Part III.

1.2 *Types of Domestic Incinerators.*

Domestic type incinerators may be either of the type installed as a complete unit and not requiring field construction, or of the type designed to be encased in brick or installed in a masonry wall or chimney.

1.3 *Design and Construction.*

(a) Incinerators of this type should be refractory-lined or insulated with heat-insulating material to reduce outside surface temperatures. Incinerators not refractory-lined or insulated should be restricted to use out of doors or in one or two family dwellings, or small establishments requiring only intermittent firing of small quantities of waste.

(b) Domestic type incinerators should be of approved types. The design shall be such that when installed in accordance with the manufacturer's directions and specified clearances, the continued operation of the unit at maximum burning rate of shredded newspaper for a period of at least one hour will not raise the temperature of surrounding walls, floors or ceilings constructed of combustible material more than 90° F. above normal room temperature. Under these conditions of testing there shall be no cracking, warping or other failure of structural parts in such manner as to permit flame passage or emission of combustion gases or sparks to the exterior.

1.4 *Gas Burner Connections.*

(a) Where a gas burner is provided, the gas installation shall conform to the Standard for the Installation of Gas Piping and Gas Appliances in Buildings, No. 54.

(b) A shut-off cock shall be provided at an accessible location in the gas line to the burner. Incinerators for use with liquefied petroleum gas, and those furnished with means for automatic ignition of the gas at the main burner shall be equipped with a device which will automatically shut off the main gas supply in the event the means of ignition becomes inoperative, or the means of keeping the valve of the device open becomes inoperative, or both. Where liquefied petroleum gas is used, the arrangement shall be such as to shut off the gas supply to the pilot burner also. The pilot burner should be so located as to insure ignition of the main burner. It should be connected to the gas supply line ahead of all controls except gas pressure regulators.

1.5 *Electrical Connections.*

All electrical connections to incinerators shall be installed in accordance with the National Electrical Code No. 70.

1.6 *Mounting.*

(a) Except as otherwise provided in 1.6 b, c and d, incinerators shall be mounted on the ground or on floors of fire resistive construction with non-combustible flooring or surface finish and with no combustible material against the underside thereof, or on fire resistive slabs or arches having no combustible material against the underside thereof. Such construction shall extend not less than 12 inches beyond the incinerator base on all sides except at the front or side where ashes are removed where it shall extend not less than 18 inches beyond the incinerator.

(b) Incinerators which are approved specifically for mounting on combustible floors may be installed in accordance with the conditions of such approval.

(c) Incinerators may be mounted on floors other than as specified in paragraph (a) above, provided the incinerator is so arranged that flame or hot gases do not come in contact with its base, and further provided the floor under the incinerator is protected with hollow masonry not less than 4 inches in thickness, covered with sheet metal of not less than 24 U. S. gauge. Such masonry course shall be laid with ends unsealed and joints matched in such a way as to provide a free circulation of air from side to side through the masonry. The floor for 18 inches beyond the front of the incinerator or side where ashes are removed and 12 inches beyond all other sides of the incinerator shall be protected with not less than 1/4-inch asbestos millboard covered with sheet metal of not less than No. 24 gauge or with protection equivalent thereto.

(d) Incinerators which are set on legs that provide not less than 4 inches open space under the base of the appliance may be mounted on floors other than as specified in paragraph 1.6 a, provided the appliance is such that flame or hot gases do not come in contact with its base, and further provided the floor under the appliance is protected with asbestos millboard not less than 1/4-inch thick covered with sheet metal of not less than 24 U. S. gauge. The above specified floor protection shall extend not less than 18 inches beyond the front of the incinerator or side where ashes are removed and 12 inches beyond all other sides of the incinerator.

1.7 *Clearances.*

(a) The clearances above a charging door to combustible material shall be not less than 48 inches. The clearance may be reduced to 24 inches provided the combustible material is protected with sheet metal not less than 28 U. S. gauge spaced out 1 inch on noncombustible spacers, or equivalent protection. Such protection shall extend 18 inches beyond all sides of the charging door opening.

(b) Except as otherwise provided in 1.7 c and d, incinerators shall be installed to provide clearances between the unit and combustible material of not less than 36 inches at the sides and top and not less than 48 inches at the front.

(c) Incinerators which are specifically approved for installation at lesser clearances than specified in 1.7 b above may be installed in accordance with the conditions of such approval, provided that in any case, the clearances shall be sufficient to afford ready accessibility for firing, cleanout and any necessary servicing, and with a minimum clearance of 3 inches to combustible material.

(d) When an incinerator is encased in common brick not less than 4 inches in thickness and is constructed with a fire clay lining or a lining of insulating material either between the firebox and metal casing or exterior thereto, or a combination of such lining and insulation, affording an equivalent degree of heat resistance, the clearances may be reduced to 6 inches at the sides and rear, and the clearance at the top may be reduced to 24 inches.

1.8 *Flue.*

Domestic type incinerators shall be connected to a chimney.

NOTE: (a) For details on chimneys, see the National Building Code, Article X, Chimneys, Flues and Vents.

(b) A barometric draft control installed in the flue pipe will help to reduce the temperature of flue gases entering the chimney.

1.9 *Flue Pipe.*

(a) The clear distance between a flue pipe or metal breeching and combustible material shall be not less than 18 inches; except that the clearance may be reduced to 9 inches when such combustible material is protected by 28 U. S. gauge sheet metal placed at least 1 inch from the surface to be protected on noncombustible spacers, or equivalent protection and extended not less than 12 inches beyond the flue pipe on both sides for the full length of the exposure.

(b) No flue pipe shall pass through any floor or ceiling.

(c) The flue pipe shall not pass through any walls or partitions constructed of combustible material unless protected at the point of passage by:

(1) Metal ventilated thimbles not less than 12 inches larger in diameter than the pipe, or,

(2) Metal or burned fire clay thimbles built in brick work or other approved fireproofing materials extending not less than 8 inches beyond all sides of the thimble; or

(3) In lieu of such protection, all combustible material in the wall or partition shall be cut away from the flue pipe a sufficient distance to provide the clearance required from such flue pipe; any material used to close up such opening shall be noncombustible.

1.10 *Air for Combustion and Ventilation.*

Provisions shall be made for an adequate supply of air for combustion and ventilation of the incinerator room. Where incinerators are installed in open areas such as undivided basements without storm windows or unusually tight doors in buildings of conventional construction, adequate air supply may usually be obtained through normal air infiltration. Where installed in a confined space or area separated by tight fitting partitions and doors, adequate air supply should be provided by means of an opening communicating with other areas having adequate air infiltration, or in the case of unusually tight buildings, with the outdoors. The free cross-sectional area of such opening supplying air for combustion and ventilation should normally be at least the area of the flue pipe of the incinerator.

1.11 *Refuse Chutes.*

Refuse chutes shall not feed directly into incinerators.

1.12 *Small Outdoor Waste Burners.*

Not applicable to incinerators covered by Sections 1.1 to 1.11 inclusive.

(a) Outdoor waste burners having a firebox or charging compartment of not over 10 bushels or approximately 12 cubic feet in capacity shall be considered domestic type. Larger units shall comply with Part III.

(b) Outdoor waste burners should be constructed to withstand internal temperatures of at least 1200° F. in intermittent operation and to provide resistance to alternate heating and cooling and to weather. The design should be such that during a period of at least two years of normal usage, structural parts will not warp, crack, corrode or otherwise fail in a manner so that doors or covers do not fit tightly or that masonry cracks or other openings are produced through which flying brands or sparks may pass.

(c) Outdoor waste burners shall be provided with a chimney extending not less than 12 feet above grade and equipped with an approved spark arrester.

(d) Outdoor waste burners shall not be located within 15 feet of any building or structure and generally should be so positioned that there is no direct exposure to buildings, wood fences or piled combustible materials in the event of failure of the spark arresters. Outdoor waste burners shall not be located so as to create a nuisance by reason of their smoke.

(e) Outdoor waste burners which are cracked, corroded or warped so as to permit the passage of sparks larger than those which the spark arrester is designed to restrain shall not be operated.

(f) Outdoor waste burners shall not be operated so as to create a nuisance or, in wooded areas, so as to interfere with fire spotting operations of forest wardens.

NOTE: In many jurisdictions, a permit from the fire department or forest warden is required for bonfires and waste burners. Some fire departments or fire prevention agencies and some fire wardens in wooded sections may restrict the operation of outdoor waste burners to certain hours of the day or to certain days.

PART II

FLUE-FED INCINERATORS (APARTMENT HOUSE TYPE)

2.1 *Application.*

(a) The provisions of this Part apply to incinerators having an identical refuse chute and smoke flue with provisions for feeding waste materials directly into the combustion chamber from one or more floors above the incinerator.

(b) Incinerators of this type are used in handling of ordinary combustible waste materials and garbage incidental to residential occupancy in multi-family buildings. These incinerators are also used in other residential and institutional buildings including hotels, clubs, dormitories and hospitals; also in churches, schools, restaurants and elsewhere where the waste materials to be destroyed are of a character for which the incinerator is designed.

2.2 *Provisions for Auxiliary Fuel.*

(a) Installation of gas burning devices shall be in accordance with the Standard for the Installation of Gas Piping and Gas Appliances in Buildings, No. 54. Oil burning installations shall comply with the Standard for the Installation of Oil Burning Equipment, No. 31.

(b) A shut-off cock shall be provided at an accessible location in the gas line to the burner. Incinerators for use with liquefied petroleum gas, those having an input of more than 50,000 B.T.U. per hour and those furnished with means for automatic ignition of the gas at the main burner shall be equipped with a device which will automatically shut off the main gas supply in the event the means of ignition becomes inoperative, or the means of keeping the valve of the device open becomes inoperative, or both. Where liquefied petroleum gas is used the arrangement shall be such as to shut off the gas supply to the pilot burner also. The pilot burner should be so located as to insure ignition of the main burner. It should be connected to the gas supply line ahead of all controls except gas pressure regulators.

2.3 *Incinerator Combustion Chambers.*

(a) Enclosing walls of combustion chambers having a horizontal combined hearth and grate area of 7 square feet or less, except as provided in 2.3 c, shall be constructed of clay or shale brickwork not less than 4 inches thick with a lining of 4½ inches of fire brick.

(b) Enclosing walls of combustion chambers having a horizontal combined hearth and grate area of 7 square feet or less, except as provided in 2.3 c, shall be constructed of not less than 8 inches of clay or shale brickwork and 4½ inches of fire brick as a lining with a space between the clay or shale brickwork and the fire brick lining sufficient to provide for expansion and contraction.

(c) Other constructions may be used if equivalent to the constructions outlined in the preceding paragraphs, in structural strength, insulating value and ability to withstand thermal expansion and flame impingement.

(d) Fire brick shall be laid in high temperature cement or fire clay mortar. All common brickwork shall be laid with full, push filled, cross and bed mortar joints.

(e) No metal stays, lintels not part of a door frame casting, or other supports shall be exposed to the interior of the furnace or the products of combustion, where auxiliary fuel is provided or where the incinerator is designed for operation at or above 1000° F.

2.4 *Combined Refuse Chute and Smoke Flue.*

(a) The flue of flue-fed incinerators shall serve the incinerator only and be used for no other purpose.

(b) The flue shall be constructed straight and plumb below the uppermost service opening and shall be smooth on the inside.

(c) The size of incinerator flues shall be in accordance with the following:

1. Where not more than one service opening is provided, the size of flue shall be not less than 14 by 14 inches or 196 square inches, inside measurements, except that in one family dwellings the size shall not be less than 12 by 12 inches or 144 square inches.

2. Where two to six service openings are provided, the size of flue shall be not less than 18 by 18 inches or 324 square inches, inside measurements.

3. Where seven or more service openings are provided, the size of flue shall be not less than 22 by 22 inches or 484 square inches, inside measurements.

(d) A flue serving an incinerator with a combustion chamber having a horizontal combined hearth and grate area of 7 square feet or less shall be enclosed with walls of clay or shale brickwork not less than 4 inches thick with a lining of 4½ inches of fire brick for a distance of not less than 10 feet above the roof of the combustion chamber; beyond this point flue enclosing walls shall consist of not less than 8 inches of clay or shale brickwork with a standard fire clay flue lining not less than ⅝-inch in thickness extending from the top of the fire brick lining to the top of the flue.

(e) A flue serving an incinerator with a combustion chamber having a horizontal combined hearth and grate area exceeding 7 square feet shall be enclosed with walls of clay or shale brickwork not less than 4 inches thick with a lining of 4½ inches of fire brick for a distance of not less than 40 feet above the roof of the combustion chamber; beyond this point, flue enclosing walls shall consist of not less than 8 inches of clay or shale brickwork with a standard fire clay flue lining extending from the top of the fire brick lining to the top of the flue.

(f) Other constructions may be used if equivalent to the constructions outlined in the preceding paragraphs, in structural strength, insulating value and ability to withstand thermal expansion and flame impingement.

(g) Fire brick and all common brickwork used in construction of chimney shall be laid as given under 2.3 d.

(h) A clearance of not less than 2 inches shall be provided between the outside face of masonry enclosing a flue and combustible material.

(i) A flue that is divided into two channels, one for feeding refuse and the other for the discharge of combustion gases, shall be constructed as specified herein for a combined refuse chute and flue.

(j) Chimneys of flue-fed incinerators shall be supported on foundations of masonry or reinforced concrete or other noncombustible material having a fire resistance rating of not less than 3 hours. They shall be constructed so as not to place excessive stress upon the roof of the combustion chamber.

(k) Chimneys of flue-fed incinerators shall extend at least 4 feet above sloping roofs measured from the highest point at which the chimney passes through the roof and at least 8 feet above flat roofs. In either case, the chimney shall extend at least 2 feet above any ridge, parapet, cornice, penthouse or other obstruction within 20 feet.

(l) All flues shall terminate in a substantially constructed spark arrester with openings not greater than ½ inch, or be provided with other suitable means for avoiding discharge of fly particles. Expansion chambers used as a secondary combustion chamber shall be constructed equivalent to that of the incinerator combustion chamber, Section 2.3. Those used only for settling shall be of construction equivalent to that of the upper portion of incinerator chimney, and with clearances to combustible material as specified by paragraph (h) of this section. Expansion chambers shall be provided with substantial noncombustible supports. Every expansion chamber shall have a vent of cross-sectional area at least equal to that of the flue.

2.5 *Service Openings to Incinerators.*

(a) The daylight area of each service opening shall be limited to one-third of the cross-sectional area of the flue, except that in one family dwellings the service opening may be one-half the cross-sectional area of the flue. In cases where flue area exceeds 22 by 22 inches, no service opening shall be used that has an area in excess of 160 square inches.

(b) All service openings into an incinerator flue shall be provided with a hopper or other charging device constructed of metal of sufficient thickness and durability to prevent cracking, breakage or deformation in normal usage. Such hopper or other charging device shall be firmly built into the masonry and shall be so designed and installed that no part will project into the flue and that the opening to the flue interior will be closed off while the service opening (hopper) door is fully open. The hopper or other device shall be counterweighted or otherwise devised so that it will close automatically upon release and be so constructed as to be tightly fitted when in the closed position.

(c) No service opening shall be installed in any part of the combustion zone of an incinerator.

(d) Instructions shall be posted at each service opening stating that waste is to be deposited only in bags or similar wrappings and warning against introduction of loose dusty materials, flammable liquids or compounds, or bulky or unwieldy articles into the chute opening.

2.6 *Mounting.*

Incinerators shall be set on proper foundations on the ground or on fire resistive floors with no combustible material on the underside thereof.

2.7 *Clearances.*

Flue-fed incinerators should be installed to provide clearance to combustible material of not less than 18 inches above and at the sides and rear and not less than 48 inches at the front of the incinerator, provided that for a flue-fed incinerator encased in brick, the clearance above and at the sides and rear may be 12 inches. A clearance of not less than 12 inches should be provided from the flue-fed incinerators to walls or ceilings of noncombustible construction which have combustible material placed on the outer or upper sides thereof, or which due to occupancy may have combustible material so placed.

2.8 *Incinerator Rooms.*

(a) Incinerators in which the combined hearth and grate area of the combustion chamber is 7 square feet or less should be enclosed within a room separated from other parts of the building by walls, and floor and ceiling assemblies having a fire resistance of not less than one hour, and used for no other purpose except storage of containers of waste materials and refuse to be burned, and building heating equipment. In private dwellings occupied by not more than two families, enclosing walls may be omitted, provided minimum clearances prescribed for domestic type incinerators are provided.

(b) Incinerators in which the combined hearth and grate area of the combustion chambers exceeds 7 square feet shall be enclosed within a room separated from other parts of the building by walls, and floor and ceiling assemblies constructed of noncombustible material and having a fire resistance rating of not less than 2 hours and used for no other purpose except storage of waste material and refuse containers, and building heating equipment.

(c) Door or other openings in rooms containing incinerators communicating with other areas of the building shall be protected by approved self-closing or automatic fire doors suitable for Class B situations.

(d) Rooms containing incinerators shall be supplied with an adequate amount of air for combustion and ventilation. Air supply may be furnished by one of the following means:

1. A screened or louvered ventilator, door or window opening or other suitable air intake. If communicating to other parts of the building the opening shall be protected by an approved fire damper.
2. A duct leading from the incinerator room to the outside air.
3. A duct leading to a boiler or furnace room cut off as prescribed above and provided with sufficient air supply for both rooms.

(e) Ducts extending from an incinerator room through other parts of a building shall be constructed and protected in accordance with the Standard for the Installation of Air Conditioning and Ventilating Systems of Other than Residence Type, No. 90A.

PART III

COMMERCIAL AND INDUSTRIAL TYPE INCINERATORS

3.1 *Application.*

The following provisions for commercial and industrial type incinerators apply to incinerators, other than those covered by Part I domestic type and Part II flue-fed (apartment house) type, intended for the reduction of rubbish, garbage, by-product wastes and other types of waste matter resulting from or incidental to any class of occupancy.

3.2 *Provisions for Auxiliary Fuel.*

(a) Installation of gas burning devices shall be in accordance with the Standard for the Installation of Gas Piping and Gas Appliances in Buildings, No. 54. Oil burner installations shall conform with the Standard for the Installation of Oil Burning Equipment, No. 31.

(b) A shut-off cock shall be provided at an accessible location in the gas line to the burner. Incinerators for use with liquefied petroleum gas, those having an input of more than 50,000 B.T.U. per hour and those furnished with means for automatic ignition of the gas at the main burner shall be equipped with a device which will automatically shut off the main gas supply in the event the means of ignition becomes inoperative, or the means [of] keeping the valve of the device open becomes inoperative, or both. Where liquefied petroleum gas is used, the arrangement shall be such as to shut off the gas supply to the pilot burner also. The pilot burner should be so located as to insure ignition of the main burner. It should be connected to the gas supply line ahead of all controls except gas pressure regulators.

3.3 *Incinerator Combustion Chambers.*

(a) Incinerators shall have the enclosing walls of combustion chambers constructed of clay or shale brick not less than 8 inches in thickness with a lining of fire brick not less than 4½ inches thick. Thicker fire brick may be needed for proper support of large walls, or to allow continuous operation at high temperatures, or to provide for flame impingement, spalling, or mechanical injury from operating tools, etc. Provision shall be made to allow for expansion and contraction of the fire brick. Other constructions may be used if equivalent in structural strength, insulating value and ability to withstand thermal expansion and flame impingement.

(b) Enclosing walls of incinerators shall be strongly braced and stayed with structural steel shapes designed to withstand interior thrusts and support door and appurtenant assemblies, except that intermittent duty incinerators not over 85 cubic feet in capacity and burning not over 165 pounds per hour need not have a steel frame if otherwise constructed to conform to Par. 3.3 a.

(c) Fire brick shall be laid in high temperature cement or fire clay mortar. All common brickwork shall be laid with full, push-filled, cross and bed mortar joints.

(d) No metal stays, lintels or other supports shall be exposed to the interior of the combustion area.

3.4 *Clearances.*

Commercial and industrial incinerators should be installed to provide a clearance to combustible material of not less than 36 inches at the sides and rear, and not less than 48 inches above, and not less than 8 feet at the front of the incinerator provided that for a commercial and industrial incinerator encased in brick the clearance above may be 36 inches and at the sides and rear it may be 18 inches. A clearance of not less than 1 inch should be provided from commercial and industrial incinerators to walls or ceilings of noncombustible construction. Under no circumstances shall the walls of the incinerator be used as a part of the structural walls of the building.

3.5 *Incinerator Rooms or Compartments.*

(a) Incinerators in which the combined hearth and grate area of the combustion chamber is 7 square feet or less should be enclosed within a room separated from other parts of the building by walls and floor and ceiling assemblies having a fire resistance rating of not less than one hour, with floor of earth or other noncombustible material, and used for no other purpose except storage of containers of waste materials and refuse to be burned, and building heating equipment. Openings to such rooms shall be protected by approved self-closing or automatic fire doors suitable for Class B situations.

(b) Incinerators in which the combined hearth and grate area of the combustion chamber exceeds 7 square feet shall be enclosed within a room separated from other parts of the building by walls and floor and ceiling assemblies constructed of noncombustible material and having a fire resistance rating of not less than two hours, with floor of earth or other noncombustible material, and used for no other purpose except storage of containers of waste material and refuse to be burned, and building heating equipment. Openings to such rooms shall be protected by approved self-closing or automatic fire doors suitable for Class B situations.

(c) Automatic sprinklers are recommended in the incinerator room, also a short length of hand hose connected to a suitable water supply.

3.6 *Rubbish or Refuse Chutes.*

Rubbish or refuse chutes other than charging chutes covered by Section 3.9 shall rest upon substantial noncombustible foundations. Enclosing walls of such chutes shall consist of 8 inches of clay or shale brickwork or 6 inches of reinforced concrete. Such chutes shall extend at least 4 feet above the roof and be covered by a metal skylight glazed with thin plain glass.

3.7 *Chute Terminal Rooms or Bins.*

(a) Rubbish or refuse chutes shall terminate or discharge directly into a room or bin separated from the incinerator room and from other parts of the building by walls, and floor and ceiling assemblies having a fire resistance rating equal to that specified for the chute. Openings to such rooms or bins shall be protected by approved self-closing or automatic fire doors suitable for Class B situations.

(b) Rubbish or refuse chutes other than charging chutes covered by Section 3.9 shall not discharge directly into an incinerator.

(c) Automatic sprinklers, properly installed, provide a reliable and effective means for fire extinguishment and should be installed in all chute terminal rooms or bins, particularly where waste handled is of a readily combustible character. A short length of hand hose connected to a suitable water supply should also be provided. Fires of the nature likely to occur at chute terminals are generally difficult to control by ordinary means due to the large amount of smoke evolved and consequent difficulty of access by the fire department. Automatic extinguishment of such fires in the incipient stage is therefore of primary importance.

3.8 *Service Openings in Rubbish or Refuse Chutes.*

Each service opening in a rubbish or refuse chute shall be protected by an approved self-closing fire door suitable for Class B situations or an approved chute door. Every such service opening shall be enclosed in a room or compartment separated from other parts of the building by walls and floor and ceiling assemblies having a fire resistance rating of not less than one hour with openings to such room or compartment protected by approved fire doors suitable for Class B situations.

3.9 *Charging Chutes and Enclosures.*

(a) Where the combustion chamber of an incinerator is charged through the floor above such incinerator, the charging chute shall be constructed of not less than No. 12 U. S. gauge steel casing, lined with not less than 4½ inches of fire brick or equivalent refractory. Such charging chute shall not exceed 6 feet in length measured from the floor opening to the oustide of the roof of the incinerator combustion chamber, unless approved means are provided to prevent the charging chute from discharging gases resulting from combustion into the charging room. When a top charging extension is provided, it shall be lined with refractory material not less than 4½ inches thick. The charging chute opening shall be protected by a cover extending beyond the edges of the opening for at least 2 inches on all sides, and lined with not less than 2½ inches of refractory material.

(b) Charging chute floor openings shall be located in a room with walls and floor and ceiling assemblies having a fire resistance rating of not less than two hours, with openings protected by approved self-closing or automatic fire doors suitable for Class A situations, except that where the room is protected by an approved system of automatic sprinklers the walls and floor and ceiling assemblies may have a fire resistance rating of not less than one hour and the door may be one approved for Class B situations. Such doors shall be kept closed during the charging operation; also at other times except when delivering waste material to the room.

3.10 *Automatic Feeding or Stoking Systems.*

No system for the automatic transfer of waste materials from a refuse chute terminal room or bin to an incinerator or other means of automatic feeding or stoking shall be provided, except by special permission of the authority having jurisdiction. This provision shall not apply to charging chutes covered by Section 3.9.

NOTE: In specific cases where arrangements are made for the mechanical handling of waste material and automatic stoking of incinerators, which would not introduce an unreasonable hazard, authorities having jurisdiction may permit such arrangements, taking into account the layout of the incinerator system as a whole, its relation to the rest of the building, the competence and continuity of personal supervision attending the operation, the presence or absence of complete sprinkler protection, ventilation, access for fire fighting and other pertinent factors. See also Standards for the Installation of Blower and Exhaust Systems for Dust, Stock and Vapor Removal or Conveying, No. 91.

3.11 *Incinerator Chimney or Flue Connections or Breechings.*

(a) The flue pipes or breechings connecting incinerators to chimneys or flues, except as provided in 3.11 b, shall be constructed of not lighter than No. 16 U. S. gauge steel when they are 12 inches or less in diameter or greatest dimension and of not lighter than No. 12 U. S. gauge steel when they exceed 12 inches in diameter or greatest dimension. In addition, they shall be lined with not less than 2½ inches of fire brick, laid in high temperature cement or fire clay mortar, when they are more than 12 inches but not in excess of 18 inches in diameter or greatest dimension and with not less than 4½ inches of fire brick when they are over 18 inches.

(b) Flue pipes of incinerators specially constructed to produce low flue gas temperatures, and incinerator flue pipes not over 10 inches in diameter and not over 8 feet long, may be of flue tile properly supported and insulated or of other suitable construction, without fire brick lining, where located entirely within the incinerator room and approved by the authority having jurisdiction.

(c) Where incinerator flue pipes or breechings lead into and combine with flue connections or breechings of other appliances such other flue pipes shall also be lined from this point to the chimney as specified in 3.11 a and b for incinerator flue connections, except that lining of this portion may be omitted where the cross-sectional area of such other flue pipe is at least equal to the area of the incinerator flue pipe or breeching and the combined breeching is large enough for full load conditions of both services and will carry flue gases at a temperature not higher than 900° F.

(d) Clearance between incinerator flue pipes or breechings and combustible material shall be not less than 36 inches.

3.12 *Incinerator Flues and Chimneys.*

(a) Flues shall be designed and proportioned to provide adequate draft for proper operation of the incinerator connected.

(b) Flues, except as provided in 3.12 c and d, shall be enclosed by not less than 8 inches of clay or shale brickwork or reinforced concrete or by a metal chimney, lined with fire brick not less than 4½ inches thick for the full height of the flue.

(c) Incinerators of the sizes and types permitted by 3.11 b to have flue pipes without fire brick lining may be connected to chimneys constructed of 8 inches of clay or shale brickwork or reinforced concrete, lined with standard fire clay flue lining, or to a metal chimney.

(d) Other constructions may be used if equivalent to the construction outlined in the preceding paragraphs, in structural strength, insulating value and ability to withstand thermal expansion and flame impingement.

(e) Fire brick and other refractory lining shall be laid in high temperature cement or fire clay mortar.

(f) Chimneys shall be supported on foundations of masonry or reinforced concrete or other noncombustible material having a fire resistance rating of not less than 3 hours. They shall be constructed so as not to place excessive stress upon the roof of the combustion chamber.

(g) A clearance of not less than 4 inches shall be provided between the exterior surface of chimneys and combustible material.

(h) Chimneys shall extend at least 4 feet above sloping roofs measured from the highest point at which the chimney passes through the roof and at least 8 feet above flat roofs. In either case, the chimney shall extend at least 2 feet above any ridge, parapet, cornice, penthouse or other obstruction within 20 feet.

(i) Incinerators may be connected to industrial or similar chimneys serving heat producing appliances provided the cross-sectional area of such chimney is adequate for the combined services and its construction is suitable for the chimney flue gas temperature.

3.13 *Expansion Chambers or Spark Arresters.*

Incinerators used for the burning of rubbish or other readily combustible solid waste material shall include effective means for arresting sparks and fly particles, such as an expansion chamber, baffle walls, or other effective arrangement, or the flues or chimneys of such incinerators shall be provided with an approved spark arrester having openings not greater than ¾-inch and preferably ½-inch.

3.14 *Ventilation of Incinerator Rooms.*

Rooms containing incinerators shall be supplied with an adequate amount of air for combustion and ventilation. Air supply may be furnished by one of the following means:

1. A screened or louvered ventilator, door or window opening or other

suitable air intake. If communicating to other parts of the building the opening shall be protected by an approved fire damper.

2. A duct leading from the incinerator room to the outside air.

3. A duct leading to a boiler or furnace room cut off as prescribed in 3.5 a or b for incinerators of given capacity and provided with sufficient air supply for both rooms.

Ducts extending from an incinerator room through other parts of a building shall be constructed and protected in accordance with the Standard for the Installation of Air Conditioning and Ventilating Systems of Other than Residence Type, No. 90A.

3.15 *Outdoor Installations.*

(a) Outdoor installations shall conform to the preceding sections in so far as applicable, and in addition shall comply with the provisions of this section.

(b) Incinerators shall be so located as not to introduce any direct exposure to adjacent buildings, structures, or outside storages of combustible stock or material in process due to handling or stoking of refuse or in the event of failure of spark arresters.

(c) Where substantial amounts of rubbish or similar combustible refuse are involved, a bin or enclosure of noncombustible construction should be provided to confine waste material to designated areas prior to burning.

DEFINITIONS

Combustible material as pertaining to materials adjacent to or in contact with heat producing appliances, flue pipes and vent connectors, steam and hot water pipes, and warm air ducts means material made of or surfaced with wood, compressed paper, plant fibers or other material that will ignite and burn. Such material shall be considered as combustible even though flameproofed, fire retardant treated, or plastered. Gypsum or other wallboards that are surfaced with combustible material are classified as combustible.

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Date Due

Due	Returned	Due	Returned
AUG 7 6 SEP	SEP 1 2 '72		
DEC 1 5 '72	DEC 2 2 '72		
APR 2 6 '73	APR 9 '73		
DEC 6 '73	NOV 2 0 '73		
MAR 1 5 '74	MAR 7 '74		
NOV 1 '74	OCT 1 '74		
OCT 15 '75	SEP 2 9 '75		
NOV 2 0 '75	NOV 1 9 '75		
JUN 0 4 '76	JUN 0 7 '76		
NOV 3 '76	NOV 0 9 '76		
DEC 1 0 '76	DEC 9 '76		
JUN - 3 '77	MAY 2 5 '77		
JUN 1 0 '77	JUN 6 '77		
AUG 25 '78	AUG 2 8 '78		
DEC 8 '78	DEC 5 '78		
FEB 8 '79	FEB 8 '79		

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